REGULATION OF RADIOACTIVE FRACKING WASTE

*Elizabeth Ann Glass Geltman & Nichole LeClair**

Introduction 3
I. Generating TENORM Waste in Oil and Gas Production 6
II. Potential Environmental and Health Risks from TENORM Waste 8
III. Disposal Options for TENORM and NORM 13
IV. Federal Oversight of NORM and TENORM 16
V. NORM & TENORM Regulation in the States 18
A. NORM & TENORM Regulation in States with Oil & Gas Drilling 26
1. Texas 26
2. Kansas 29
3. Oklahoma 30
4. Pennsylvania 31
5. West Virginia 33
6. California 33
7. Colorado 34
8. Illinois 36

* Prof. Geltman is an Associate Professor at the CUNY School of Public Health, Secretary of the Law Section of the American Public Health Association and Director of the Atlantic Emerging Technologies & Industrial Hygiene Training Center funded by the *National Institute of Environmental Health Sciences* (NIEHS) Superfund Hazardous Substances Basic Research and Training Program, and the author of seventeen books on environmental law and policy. Nichole LeClair is a Research Fellow with the Atlantic Emerging Technologies & Industrial Hygiene Training Center and an MPH graduate of the CUNY School of Public Health.

This study was supported by the Temple University Center for Health Law, Policy & Practice and the Robert Wood Johnson Foundation Policy Surveillance Program. Preliminary results of this paper were presented as a poster at the 2016 American Public Health Annual Meeting and as a poster at the 2017 CUNY School of Public Health Research Day; the authors thank conference participants for comments on the posters. The authors also thank our team of researchers at Hunter College for assistance in coding: Emily Austerberry, Mustafa Ali, Emilio Cintron, Adam Hess, Hailu Tedia, and Henry Akinleye.

9. Wyoming 37
10. Louisiana 38
11. New Mexico 39
12. Kentucky 41
13. Utah 42
14. New York 43
15. Montana 43
16. Michigan 45
17. Arkansas 46
18. North Dakota 46
19. Tennessee 48
20. Virginia 49
21. Mississippi 49
22. Nebraska 50
23. Ohio 51
24. Washington 52
25. South Dakota 52
26. Oregon 53
27. Arizona 53
28. Idaho 53
B. States with Active Wells that Have No NORM & TENORM Regulations 54
C. NORM & TENORM Regulations in States Without Oil & Gas Drilling 55
VI. By the Numbers 58
Conclusion 61

INTRODUCTION

In 2015, producers in the United States extracted natural gas from shale at record totals. The U.S. Energy Information Administration (EIA) forecasts an increase in natural gas production.[1] Five states account for 65% of total dry, natural gas production as of 2015: Texas (26%), Pennsylvania (18%), Oklahoma (9%), Wyoming (6%), and Louisiana (6%).[2] The dramatic increase in natural gas production is the product of new technology developed under the Carter Administration during the 1970s' energy crisis.[3] By combining high-volume hydraulic fracturing (HVHF)[4] with horizontal drilling,[5] industry can tap oil and gas reserves trapped in shale using new technologies.[6]

The oil industry knew about the vast natural gas trapped in shale formations since oil and gas was discovered in Fredonia, New York, in 1821.[7] In the late 1940s, hydraulic fracturing techniques were employed for the first time to stimulate oil and gas wells; however, more advanced technologies of horizontal drilling were employed decades later to facilitate lower costs and efficiency.[8] Unconventional technology now allows what had been a nuisance gas to be drilled as an abundant energy resource.[9]

---

1. *Natural Gas Explained: Where Our Natural Gas Comes from*, U.S. ENERGY INFO. ADMIN., https://www.eia.gov/energyexplained/index.cfm?page=natural_gas_where [https://perma.cc/Q26S-HTHU] (last updated Oct. 25, 2017).
2. *Id.*
3. Gary C. Bryner, *National Energy Policy: Assessing Energy Policy Choices*, 73 U. COL. L. REV. 341, 341 (2002).
4. *See, e.g.*, Method & Materials for Hydraulic Fracturing of Wells, U.S. Patent No. 6,949,491 (filed Sept. 24, 2002) (detailing the fracturing process); *see also* R. G. Agarwal et al., *Evaluation and Performance Prediction of Low-Permeability Gas Wells Stimulated by Massive Hydraulic Fracturing*, 31 J. PETROLEUM TECH. 362, 362 (1979) (evaluating mathematical models to predict the success of hydraulic fracking).
5. *See* Gary D. Libecap, *The Political Allocation of Mineral Rights: A Re-Evaluation of Teapot Dome*, 44. J. ECON. HIST. 381, 383 (1984) (discussing the developments in horizontal drilling); Method of Horizontal Drilling, U.S. Patent No. 5,165,491 (filed Apr. 29, 1991) (detailing the horizontal drilling process); Method & Apparatus for Horizontal Drilling, U.S. Patent No. 5,148,875 (filed Sept. 24, 1991) (detailing the apparatus used to simultaneously drill and case a wellbore).
6. *See* 43 C.F.R. § 3160 (2015) (governing operations associated with production of oil and gas deposits, including hydraulic fracturing).
7. Office of Fossil Energy, *Natural Gas from Shale: Questions and Answers*, U.S. DEP'T ENERGY (Apr. 2013), https://energy.gov/sites/prod/files/2013/04/f0/complete_brochure.pdf [https://perma.cc/ZG44-B4LW].
8. *Id.*
9. *See, e.g.*, Edward W. Cook, *Oil-Shale Technology in the USA*, 53 FUEL 146,146 (1974) (discussing development of shale-oil industry); *see also* Bryner, *supra* note 3, at 341.

Larger volumes of oil and gas are now developed in areas that were once impossible to access.[10]

With improved technologies exploiting the full potential of shale formations, there has been a sharp rise in drilling in areas that historically had little or no oil and gas development.[11] Many of these new drill sites are in areas close to homes.[12] The drilling increase has led to concern about worker and public exposure to naturally occurring radioactive materials (NORM) and technologically enhanced naturally occurring radioactive materials (TENORM).[13] These wastes can contain the radioactive isotopes radium-226 (Ra-226) and radium-228 (Ra-228), which decay further into radon (Rn).[14] Exposure to radon, a form of NORM, is the leading cause of lung cancer in the United States, after smoking.[15] An important study regarding the Pennsylvanian portion of the Marcellus Shale suggests oil and gas extraction techniques, including hydraulic fracturing, correlate with elevated radon levels in drilling areas.[16] Concern for human health due to increased seismic activity,[17] along with air,[18] water,[19] light,[20] and noise

---

10. MICHAEL RATNER & MARY TIEMANN, CONG. RESEARCH SERV., AN OVERVIEW OF UNCONVENTIONAL OIL AND NATURAL GAS: RESOURCES AND FEDERAL ACTIONS 13 (Apr. 22, 2015), https://www.fas.org/sgp/crs/misc/R43148.pdf [https://perma.cc/FH34-55Q3]; *see* Anastasia Hudgins & Amanda Poole, *Framing Fracking: Private Property, Common Resources, and Regimes of Governance*, 21 J. POL. ECOLOGY 303, 310 (2014) (discussing how corporations have limited access to oil and gas); *see also* RESERVES & PROD. DIV., U.S. ENERGY INFO. ADMIN., TECHNOLOGY-BASED OIL AND NATURAL GAS PLAYS: SHALE SHOCK! COULD THERE BE BILLIONS IN THE BAKKEN? 7 (2006) (concluding that oil producers have identified "a previously overlooked resource and refined their technology and techniques in order to develop it").

11. RATNER & TIEMANN, *supra* note 10, at 13; RESERVES & PROD. DIV., *supra* note 10, at 1; *see* Hudgins & Poole, *supra* note 10, at 312 (illustrating the sharp rise in drilling in areas that once did not have oil and gas development).

12. Elisabeth N. Radow, *Homeowners and Gas Drilling Leases: Boon or Bust?*, N.Y. ST. B. ASS'N J., Nov.–Dec. 2011, at 10, 12.

13. *See generally* S. Almond et al., *The Flux of Radionuclides in Flowback Fluid from Shale Gas Exploitation*, 21 ENVTL. SCI. & POLLUTION RES. 12,316 (2014) (discussing radiation in the flowback and produced waters); Andrew J. Kondash et al., *Radium and Barium Removal Through Blending Hydraulic Fracturing Fluids with Acid Mine Drainage*, 48 ENVTL. SCI. & TECH. 1334 (2013) (outlining methods to remediate NORM waste); Valeria J. Brown, *Radionuclides in Fracking Wastewater: Managing a Toxic Blend*, ENVTL. HEALTH PERSP. Feb. 2014, at A50–A55 (2014) (discussing fracking wastewater).

14. Joan A. Casey et al., *Predictors of Indoor Radon Concentrations in Pennsylvania, 1989–2013*, 123 ENVTL. HEALTH PERSP. 1130, 1130 (2015).

15. *Id.*

16. *Id.*

17. *See, e.g.*, William L. Ellsworth, *Injection-Induced Earthquakes*, 341 SCI. 142, 142–44 (2013) (detailing the correlation between increases in injection-style mining and seismic activity); NORMAN R. WARPINSKI ET AL., SOC'Y OF PETROLEUM ENG'RS, MEASUREMENTS OF HYDRAULIC-FRACTURE-INDUCED SEISMICITY IN GAS SHALES, 1 (2012) (explaining the risk of seismic activity from hydraulic fracturing); *see also* David M. Kargbo et al., *Natural Gas Plays in the Marcellus Shale: Challenges and Potential Opportunities*, 44 ENVTL. SCI. & TECH. 5679, 5680 (2010) (listing the seismic issues that can arise from drilling); MARK ZOBACK ET AL., ADDRESSING THE ENVIRONMENTAL

pollution,[21] has led some states to draft new policies. These policies add protective measures in the form of laws, regulations, and guidance documents for a variety of identified perils, including radiation exposure. [22] A growing number of states with oil and gas development created standards for the disposal of NORM and TENORM wastes.[23] Given the precipitous rise of oil and gas extraction from shale in the past decade, states must evaluate measures to determine whether they need further worker and public protections. Federal regulatory policies set a 10% limit on the occupational whole-body dose that workers involved in these operations rarely exceed.[24] While many states impose general radiation provisions, some oil and gas states deem such provisions insufficient. Instead, those

---

RISKS FROM SHALE GAS DEVELOPMENT 9 (2010), https://www.worldwatch.org/files/pdf/Hydraulic%20Fracturing%20Paper.pdf [https://perma.cc/TCW2-5TTY] (discussing the potential link between seismic activity and hydraulic fracturing waste disposal); Cliff Frohlich & Michael Brunt, *Two-Year Survey of Earthquakes and Injection/Production Wells in the Eagle Ford Shale, Texas, Prior to the M_W 4.8 20 October 2011 Earthquake*, 379 EARTH & PLANETARY SCI. LETTERS 56, 56 (2013) (providing a region-specific study).

18. *See, e.g.*, Aviva Litovitz et al., *Estimation of Regional Air-Quality Damages from Marcellus Shale Natural Gas Extraction in Pennsylvania*, 8 ENVTL. RES. LETTERS 1, 1 (2013) (compiling conventional air pollutant data in Pennsylvania and assessing its monetary value).

19. *See generally* R. D. Vidic et al., *Impact of Shale Gas Development on Regional Water Quality*, 340 SCI. 826 (2013) (discussing the environmental risks of hydraulic fracturing on regional water qualities).

20. *See generally* Steve Albers & Dan Duriscoe, *Modeling Light Pollution from Population Data and Implications for National Park Service Land*, 18 GEORGE WRIGHT FORUM 56, 56 (2001) (discussing light pollution as a concern for human health due to increased seismic activity).

21. *See* Jacob A. Benfield et al., *Aesthetic and Affective Effects of Vocal and Traffic Noise on Natural Landscape Assessment*, 30 J. ENVTL. PSYCHOL. 103, 103 (2010) (researching the effects of noise pollution on the enjoyment of the natural landscape); Jesse R. Barber et al., *The Costs of Chronic Noise Exposure for Terrestrial Organisms*, 25 TRENDS ECOLOGY & EVOLUTION 180, 187 (2010) (discussing the cumulative effects of noise management, and how it exacerbates the problems posed by habitat fragmentation).

22. *See* Elizabeth Glass Geltman, *Drilling for Common Ground: How Public Opinion Tracks Experts in the Debate over Federal Regulation of Shale Oil & Gas Extraction (aka Fracking)*, 35 VA. ENVTL. L.J. 59, 84–85 (2016) (discussing state laws, regulations, and guidance documents that add a level of protection); *see also* Elizabeth Ann Glass Geltman, *Beyond Baby Steps: An Empirical Study of the Impact of Environmental Justice Executive Order 12898*, 39 FAM. & COMMUNITY HEALTH 143, 148 (2016) (discussing how Clinton's Executive Order 12,898 paved the way for new laws, policies, and regulations for environmental justice); Elizabeth Glass Geltman et al., *Impact of Executive Order 13211 on Environmental Regulation: An Empirical Study*, 89 ENERGY POL'Y 302, 302–10 (2016) (examining conservation and environmental regulations promulgated to address fracking). *See generally* Elizabeth Ann Glass Geltman, *Oil & Gas Drilling in National Parks*, 56 NAT. RESOURCES J. 145, 145 (2016) (exploring the tension between environmental protection and energy independence); *see also* Elizabeth Glass Geltman et al., *Inquiry into the Impact of Bush's Executive Order 13211 on Environmental and Public Health Regulation*, 27 FORDHAM ENVTL. L. REV. 200, 201 (2016) ("Executive Order 13,211 strikes a reasonable balance between environmental conservation and energy development.").

23. ASS'N OF STATE & TERRITORIAL SOLID WASTE MGMT. OFFICIALS, INCIDENTAL TENORM: A GUIDANCE FOR STATE SOLID WASTE MANAGER 5 (2011), http://www.astswmo.org/Files/Policies_and_Publications/Federal_Facilities/2011.04_FINAL_ASTSWMO_TENORM_Paper.pdf [https://perma.cc/P472-433Z].

24. *Id.*

states developed provisions specifically impacting oil and gas operations for the same reason that states developed provisions specific to medical use of radiation.[25]

This article explores and evaluates how states handle and regulate the disposal of NORM and TENORM wastes from unconventional oil and gas operations and determines the most protective practices to reduce radiological health effects. The study concludes that although some states are regulating NORM and TENORM, other states may be inadequately addressing these wastes. Multiple agencies having concurrent jurisdiction to handle waste further complicate the issue. Clearer guidance, laws, and regulations may be needed to facilitate safety and health measures in states where inadequacies could potentially harm humans, animals, and the environment.

I. GENERATING TENORM WASTE IN OIL AND GAS PRODUCTION

Oil and natural gas trapped in deep, porous rock or reservoirs can move under natural pressure to the surface during conventional drilling; however, impermeable rocks, such as shale, hinder the natural flow of oil and gas.[26] Hydraulic fracturing can release the trapped methane by injecting fluids containing pressurized water, sand, and chemicals to create and maintain fractures, increase permeability, and extract oil or gas.[27] Once injected into the well, the fracturing fluid returns to the surface as flowback and produced water containing NORM or TENORM.[28]

Produced water is a mixture of both organic and inorganic materials.[29] Radiation exposure occurs through the co-precipitation of radioactive NORM, such as radium and barium.[30] Water and fracturing fluids surfacing during the flowback process can contain a wide range of NORM and TENORM contaminants, potentially harming water quality.[31] In addition, radon-222 gas (Rn-222) can follow the processing and distribution systems, elevating the amounts of lead-210 (Pb-210) on the downstream equipment.

---

25. *Id.*
26. *See* Office of Fossil Energy, *Natural Gas from Shale: Questions and Answers*, U.S. DEP'T OF ENERGY, https://energy.gov/sites/prod/files/2013/04/f0/complete_brochure.pdf [https://perma.cc/SPK6-RWZ4] (last visited Feb. 4, 2018) (defining hydraulic fracking practices).
27. *Id.*
28. *Id.*
29. A. Fakhru'l-Razi et al., *Review of Technologies for Oil and Gas Produced Water Treatment*, 170 J. HAZARDOUS MATERIALS 530, 531 (2009).
30. *Id.* at 533.
31. *See id.* at 546 (proposing alternative methods of using contaminated flowback water).

The co-precipitation of radium isotopes with other minerals in produced water and flowback accumulate in the pipelines forming scales and sludges that contain higher radioactivity concentrations.[32] These radioactive materials containing radium and other progenies can be found in pipeline scrapings, sludge accumulating in tank bottoms, flowback, produced sands, and produced waters.[33] A recent study reported radium concentrations of scales and sludge amounting to 94,500 picocuries per gram (pCi/g) and 59,265 pCi/g for Ra-226 and Ra-228, respectively.[34] Other studies evaluating radium concentrations found median levels of 5,490 pCi/g and 1,727 pCi/g in the New York and Pennsylvania Marcellus Shale, respectively.[35]

Flowback and produced water contain high concentrations of brines and dissolved chemicals, with the salt content sometimes reaching very high concentrations.[36] While radium's parent isotopes uranium-238 (U-238) and thorium-232 (Th-232) are insoluble, radium is highly soluble in brines and can be effectively mobilized into the formation water.[37] As a result, flowback and produced water contains Ra-226, Ra-228, and their decay products. They subsequently find their way into various forms of NORM and TENORM waste, with concentrations reported from a few picocuries per gram to thousands of picocuries per gram.[38] For this reason, radium and radon are far more problematic than their parent NORM isotopes due to their solubility in water and tendency to concentrate as the salinity increases.[39]

---

32. *Id.*

33. Alisa L. Rich & Ernest C. Crosby, *Analysis of Reserve Pit Sludge from Unconventional Natural Gas Hydraulic Fracturing and Drilling Operations for the Presence of Technologically Enhanced Naturally Occurring Radioactive Material (TENORM)*, 23 NEW SOLUTIONS 117, 118 (2013).

34. M.H. Paranhos Gazineu et al., *Radioactivity Concentration in Liquid and Solid Phases of Scale and Sludge Generated in the Petroleum Industry*, 81 J. ENVTL. RADIOACTIVITY 47, 52 (2005).

35 . E.L. ROWAN ET AL., U.S. GEOLOGOCIAL SURV., RADIUM CONTENT OF OIL AND GAS-FIELD PRODUCED WATERS IN THE NORTHERN APPALACHIAN BASIN (USA): SUMMARY AND DISCUSSION OF DATA 15 (2011).

36. ARTHUR P. SCHMIDT, NATURALLY OCCURRING RADIOACTIVE MATERIALS IN THE GAS AND OIL INDUSTRY: ORIGIN, TRANSPORT AND DEPOSITION OF STABLE LEAD AND ^{210}PB FROM DUTCH GAS RESERVOIRS 20 (2000); Gary R. Walter et al., *Effect of Biogas Generation on Radon Emissions from Landfills Receiving Radium-Bearing Waste from Shale Gas Development*, 62 J. AIR & WASTE MGMT. ASS'N 1040, 1040 (2012).

37. Walter et al., *supra* note 36, at 1041.

38. Nathaniel R. Warner et al., *Impacts of Shale Gas Wastewater Disposal on Water Quality in Western Pennsylvania*, 47 ENVTL. SCI. & TECH. 11849, 11853 (2013).

39. Nathaniel R. Warner et al., *Geochemical Evidence for Possible Natural Migration of Marcellus Formation Brine to Shallow Aquifers in Pennsylvania*, 109 PROC. NAT'L ACAD. SCI. U.S. 11,961, 11,961–66 (2012).

Unlike flowback[40] and produced waters,[41] drill cuttings surfacing during oil and gas development usually contain NORM.[42] Chemically, radium behaves in a manner similar to calcium and can bioaccumulate in plants and animals that make up the human food chain.[43] Drilling cuts, produced water, and other debris from the fracturing process contain isotopes of radium; although, quantities and potential radiation hazards vary depending on exposure pathways.

Radium and radon can also surface as natural gas seeps out of the well.[44] In contrast to Ra-226 and Ra-228, Rn-222 has a significantly shorter half-life of less than four days.[45] Since Rn-222 surfaces with natural gas and disperses into the atmosphere upon release, Rn-222 poses less risk than

---

40. *See generally* Noura Abualfaraj et al., *Characterization of Marcellus Shale Flowback Water*, 31 ENVTL. ENGINEERING SCI. 514 (2014) (discussing health risks from flowback); Ronald S. Balaba & Ronald B. Smart, *Total Arsenic and Selenium Analysis in Marcellus Shale, High-Salinity Water, and Hydrofracture Flowback Wastewater*, 89 CHEMOSPHERE 1437, 1437–42 (2012).

41. *See, e.g.*, Denise M. Akob et al., *Organic and Inorganic Composition and Microbiology of Produced Waters, from Pennsylvania Shale Gas Wells*, 60 APPLIED GEOCHEMISTRY 116, 121 (2015) (discussing health risks from produced waters). *See generally* Maryam A. Cluff et al., *Temporal Changes in Microbial Ecology and Geochemistry in Produced Water from Hydraulically Fractured Marcellus Shale Gas Wells*, 48 ENVTL. SCI. & TECH. 6508, 6508–09 (2014) (explaining the microbial changes in the deep subsurface areas after the hydraulic fracturing process); Kelvin Gregory & Arvind Murali Mohan, *Current Perspective on Produced Water Management Challenges During Hydraulic Fracturing for Oil and Gas Recovery*, 12 ENVTL. CHEM. 261, 263 (2015) (listing several toxic and non-toxic organic molecules founds in produced water from hydraulic fracturing); Samuel J. Maguire-Boyle & Andrew R. Barron, *Organic Compounds in Produced Waters from Shale Gas Wells*, ENVTL. SCI. PROCESSES & IMPACTS, Oct. 2014, at 2237, 2245, 2247 (identifying issues with treating produced water due to the low concentration of polyaromatic hydrocarbons even though this concentration is lower than other produced waters); Katherine J. Skalak et al., *Surface Disposal of Produced Waters in Western and Southwestern Pennsylvania: Potential for Accumulation of Alkali-Earth Elements in Sediments*, 126 INT'L J. COAL GEOLOGY 162, 162 (2014) ("Significant volumes of water are co-produced with petroleum products and if not properly handled, present a potential source of contamination to the environment."); Amit Vikram et al., *Produced Water Exposure Alters Bacterial Response to Biocides*, 48 ENVTL. SCI. & TECH. 13001 (2014) (discussing the microbial activity during the holding and reuse of hydraulic fracturing wastewater and the risk of genetic alterations resulting in altered biocide resistance).

42. Walter et al., *supra* note 36, at 1040.

43. Rich & Crosby, *supra* note 33, at 125–28 (discussing radionuclide decay and environmental and health impacts).

44. *See* MARVIN RESNIKOFF, RADIOACTIVE WASTE MGMT. ASSOCS., REVIEW OF PENNSYLVANIA DEPARTMENT OF ENVIRONMENTAL PROTECTION TECHNOLOGICALLY ENHANCED NATURALLY OCCURRING RADIOACTIVITY MATERIALS (TENORM) STUDY REPORT 1 (2015) (stating that natural gas production releases radium in many ways, including a gaseous form, and that the Marcellus Shale has "up to 32 times surface background concentrations" of radium). *See generally* MARVIN RESNIKOFF ET AL., RADIOACTIVE WASTE MGMT. ASSOCS., RADIOACTIVITY IN MARCELLUS SHALE: CHALLENGE FOR REGULATORS & WATER TREATMENT PLANTS 1 (2010) (explaining the many ways how radium and radon are brought to the surface after drilling); MELISSA BELCHER & MARVIN RESNIKOFF, RADIOACTIVE WASTE MGMT. ASSOCS., HYDRAULIC FRACTURING RADIOLOGICAL CONCERNS FOR OHIO 2 (2013) (explaining that Ra-226 does not "inexplicably disappear[] when it is brought to the surface").

45. *Id.* at 118.

TENORM waste, but poses a significant threat to indoor air levels in homes.[46]

II. Potential Environmental and Health Risks from TENORM Waste

According to the Agency for Toxic Substances Disease Registry (ATSDR), prolonged exposure to high levels of gamma radiation emitted by radium may cause adverse health effects, such as anemia, cataracts, fractured teeth, cancer, and death.[47]The Environmental Protection Agency's (EPA) drinking-water limit for Ra-226 and Ra-228 is 5 picocuries per liter (5 pCi/L).[48] EPA's soil-concentration limit for radium-226 in uranium and thorium mill tailings is 5 pCi/g in the first 15 centimeters of soil and 15 pCi/g in deeper soil.[49] State regulations often adhere to exemption limits for Ra-226 and/or Ra-228, no matter the industry.[50] Radium decaying into radon establishes another long-term health risk.[51]

Both radon and radium pose documented health risks.[52] Radon is the second leading cause of lung cancer, and some evidence suggests it may cause other cancers such as leukemia.[53] Other studies report incidences of lymphoma, bone cancer, and leukemia from drinking radium-contaminated water.[54] Radium can bioaccumulate in a number of species where it can substitute for calcium in bones, although the evidence is much more limited in people.[55] For radon, the EPA recommends an action level of 4 pCi/L of

---

46. David Vearrier et al., *Technologically Enhanced Naturally Occurring Radioactive Materials*, 47 CLINICAL TOXICOLOGY 393, 395 (2009).

47. *Public Health Statement for Radium*, AGENCY FOR TOXIC SUBSTANCES & DISEASE REGISTRY, (Dec. 1990), https://www.atsdr.cdc.gov/phs/phs.asp?id=789&tid=154 [https://perma.cc/5KDP-FP9G].

48. *Id.*

49. *Id.*

50. *See, e.g.*, ELIZABETH ANN GLASS GELTMAN & NICHOLE LECLAIR, REGULATION OF OIL AND GAS WASTES CONTAINING TENORM 2 (2016), http://monqcle.com/upload/58af149ff7d1b681571836b7/download?__hstc=194825010.d1e8d97df0db2c0d02cc561689557566.1517691381057.1517691381057.1517699216184.2&__hssc=194825010.3.1517699216184&__hsfp=1597375246 [https://perma.cc/C792-LSQ2] (describing exemption limits for 19 states that license individuals or facilities to work with NORM or TENORM).

51. *Id.*

52. *See, e.g.*, Naomi Harey et al., *Contribution of Radon and Radon Daughters to Respiratory Cancer*, 70 ENVTL. HEALTH PERSP. 17, 18 (1986) (describing the increased risk of respiratory cancer in uranium miners).

53. Gary G. Schwartz & Marilyn G. Klug, *Incidence Rates of Chronic Lymphocytic Leukemia in US States are Associated with Residential Radon Levels*, 12 FUTURE ONCOLOGY 165, 169 (2015).

54. Irina Guseva Canuet et al., *Health Effects of Naturally Radioactive Water Ingestion: The Need for Enhanced Studies*, ENVTL. HEALTH PERSP., Dec. 2011, at 1676, 1676–77.

55. Brown, *supra* note 13, at A54.

air, but cautions that health effects are seen with exposures of less than 4 pCi/L.[56] As more studies evaluate exposure and outcomes, the potential for adverse effects of radon becomes more prevalent. Thus, if areas that extract shale gas see a rise in outdoor/indoor radon levels and radium levels in TENORM waste—as indicated in one study conducted by researchers from Johns Hopkins in Pennsylvania[57]—those areas should take more protective measures to protect the public.

Flowback and produced water, if not treated, may also lead to elevated levels of total dissolved solids (TDS), salts, and hazardous chemicals containing NORM.[58] While Ra-226 and Ra-228 are most often associated with TENORM and NORM, other radionuclides in the U-238 and Th-232 decay series are projected to increase levels of radioactivity. Some propose that radioactivity is underestimated in flowback and produced water.[59] Wastewater storage impoundments (also called pits and ponds) are commonly lined with non-leaking, plastic sheeting.[60] Despite such safeguards, the potential for leakage threatens the environment and public health in weather events and other emergencies. Leaks from mechanical failures could contaminate groundwater, soil, and air. Secondary potential exposure pathways from ingesting agricultural products that contain TENORM exist, but remain mostly unstudied.[61] Other reports suggest the movement of chemicals leading to migration and concentrated NORM radionuclide levels cause pollution of aquifers from shale gas extraction techniques.[62]

Removal processes, involving deposited scales in the pipes, produce radioactive waste and pose important occupational radiation hazards to

---

56. AGENCY FOR TOXIC SUBSTANCES & DISEASE REGISTRY, U.S. DEP'T OF HEALTH & HUMAN SERV., TOXICOLOGICAL PROFILE FOR RADON 7 (2012), https://www.atsdr.cdc.gov/toxprofiles/tp.asp?id=407&tid=71 [https://perma.cc/EW2U-F2JM].

57. Casey et al., *supra* note 14, at 1136 (referencing Pennsylvania study on technologically enhanced radioactive material); *see* Andrew Nikiforuk, *Fracking Increases Radon Gas Hazard, US Study Finds*, THE TYEE (Apr. 13, 2015), https://thetyee.ca/News/2015/04/13/Fracking-Radon-Gas-Hazard/ [https://perma.cc/32GM-9SDJ] (discussing a study on the acceleration of the release of radon when fracking unconventional rock formations).

58. SCHMIDT, *supra* note 36, at 20; *see* Mei Shi et al., *Bromide: A Pressing Issue to Address in China's Shale Gas Extraction*, 48 ENVTL. SCI. & TECH. 9971, 9971 (2014) (explaining that wastewater contains "heavy metals, radioactive metals, high levels of total dissolved solids (TDS), and in some cases, elevated concentrations of bromide.").

59. Andrew W. Nelson et al., *Understanding the Radioactive Ingrowth and Decay of Naturally Occurring Radioactive Materials in the Environment: An Analysis of Produced Fluids from the Marcellus Shale*, 123 ENVTL. HEALTH PERSP. 689, 692–93 (2015) (acknowledging there are several other radionuclides that will increase the levels of radioactivity).

60. Brown, *supra* note 13, at A52.

61. Beng Ong, *The Potential Impacts of Hydraulic Fracturing on Agriculture*, 3 EUR. J. SUSTAINABLE DEV. 63, 63 (2014).

62. *Id.*

workers through external bodily exposure and inhalation of radioactive dusts.[63] As such, TENORM causes the greatest risk to workers involved in the cleaning and removal of these scales and in decontamination processes of equipment.[64] Risks exist for workers on drilling sites, maintenance workers who dismantle oil and gas equipment, and workers who recycle contaminated pipes and equipment.[65] A North Dakota Department of Health study routinely monitored various activities from unconventional oil and gas operations. This included: mixing of hydraulic fracturing fluids,[66] sludge treatment, pipe cleaning, and hauling of TENORM; finding 2.2 millirems/year, 30 millirems/year, 130 millirems/year, and 20 respectively.[67]

In addition, contaminated soil resulting from decontamination operations and other removal processes may expose the public to radiation.[68] Other routes of exposure include direct gamma radiation,

---

63. Vearrier, *supra* note 46, at 399–400.

64. Ruth McDermott-Levy et al., *Fracking, the Environment, and Health*, 113 AM. J. NURSING, June 2013, at 45, 48–49.

65. *TENORM: Oil and Gas Production Wastes*, U.S. ENVTL. PROTECTION AGENCY, https://www.epa.gov/radiation/tenorm-oil-and-gas-production-wastes (last visited Sept. 9, 2017).

66. *See* Benay Akyon et al., *Microbial Mats as a Biological Treatment Approach for Saline WasteWaters: The Case of Produced Water from Hydraulic Fracturing*, 49 ENVTL. SCI. & TECH. 6172, 6172–80 (2015) (discussing potential health impacts of wastewater); Jennifer S. Harkness et al., *Iodide, Bromide, and Ammonium in Hydraulic Fracturing and Oil and Gas Wastewaters: Environmental Implications*, 49 ENVTL. SCI. & TECH. 1955, 1960–61 (2015) (analyzing the chemical concentrations of wastewater); Avner Vengosh, *A Critical Review of the Risks to Water Resources from Unconventional Shale Gas Development and Hydraulic Fracturing in the United States*, 48 ENVTL. SCI. & TECH. 8334, 8341 (2014) (detailing the unconventional practices oil and gas production in western Pennsylvania which causes radium accumulation); Kimberly M. Parker et al., *Enhanced Formation of Disinfection Byproducts in Shale Gas Wastewater-Impacted Drinking Water Supplies*, 48 ENVTL. SCI. & TECH. 11161, 11161 (2014) ("Wastewaters associated with hydraulic fracturing . . . frequently contain high levels of halides, heavy metals, and radioactivity."); Brian G. Rahm et al., *Wastewater Management and Marcellus Shale Gas Development: Trends, Drivers, and Planning Implications*, 120 J. ENVTL. MGMT. 105, 105 (2013) (stating that over six million cubic meters of wastewater has been produced in Pennsylvania alone and suggesting the implementation of a tracking and reporting system); Mei Shi et al., *supra* note 58, at 9971 (explaining that poor management of wastewater could contaminate drinking water sources); Daniel Snyder, Impact of Oil and Gas Industry Wastewater on Water and Sediment Chemistry in One Stream in West-Central Pennsylvania (2014) (unpublished B.S. thesis, Pennsylvania State University) (discussing the potential health impact of wastewater); Jonathan B. Thacker et al., *Chemical Analysis of Wastewater from Unconventional Drilling Operations*, 7 WATER 1568, 1569 (2015) ("[T]he fate of the large volume of resulting wastewater . . . may be important in preventing environmental contamination."); Warner et al., *supra* note 39, at 11,849; Paul F. Ziemkiewicz, *Characterization of Liquid Waste Streams from Shale Gas Development*, 30 AGH DRILLING, OIL, GAS QUARTERLY 297, 302 (2013) ("Exposure to radionuclides, even at low levels can raise serious health concerns.").

67. N.D. DEP'T OF HEALTH, SUMMARY OF TENORM STUDY 1 (2014), http://www.ndhealth.gov/ehs/tenorm/ArgonneStudy/NDDoH%20SUMMARY%20OF%20TENORM%20STUDY-v.FINAL.pdf [https://perma.cc/5EWX-DEBM].

68. R.E. MCBURNEY, RADIATION PROTECTION FROM NORM AND TENORM IN THE OIL AND GAS INDUSTRY: REGULATORY AND NON-REGULATORY APPROACHES 3–4,

inhalation of dusts, ingestion of contaminated water, and ingestion of contaminated food.[69] Additionally, North Dakota's Department of Health found routine and accidental exposures; for members of the public adjacent to operating landfills, exposure was more than 0.024 millirems/year with an average exposure time of 8,760 hours/year.[70]

A study that compared radioactivity and dissolved solids in sediments, both up and downstream of a Pennsylvania wastewater treatment facility, found a 90% reduction in radioactivity in the effluent.[71] Most of the NORM radioactive constituents accumulated in sludges and disposed of in landfills exceeded federal limits, thus requiring careful monitoring for TENORM in these landfills.[72] This study highlights an important concern that the bioaccumulation of radium potentially increases public exposure to radiation.

A recent Pennsylvania case study of an abandoned mine reported drainage to be the most significant potential environmental problem impacting water quality.[73] Despite the fact the contaminated water can be reused for shale gas extraction, with both environmental and economic benefit, the possibility of radium precipitating and finding its way into municipal waste raises an important challenge.[74] Disposal of potential radium-bearing materials from TENORM waste in municipal solid waste landfills can also release radon into the atmosphere and cause a public health concern.[75]

Radioactive waste resulting from increased unconventional oil and gas drilling operations raises concern that workers and the public are not adequately guarded against possible exposure, with the latter exposed to more acute levels of ionizing radiation. Additionally, TENORM waste may contaminate well sites and subsequently spread to nearby areas through wind and water.[76] Despite concerns of radiological risks to workers, the public, and the environment, different studies suggest the risk posed by

---

http://irpa12.org.ar/KL/III.4.3/McBurney_fp.pdf [https://perma.cc/HAU3-RACA] (last visited Feb. 4, 2018).

69. *TENORM*: *Oil and Gas Production Wastes*, U.S. ENVTL. PROTECTION AGENCY, https://www.epa.gov/radiation/tenorm-oil-and-gas-production-wastes [https://perma.cc/2HX2-HNGZ] (last visited Feb. 4, 2018).

70. N.D. DEP'T OF HEALTH, *supra* note 67, at 1.

71. Tieyuan Zhang et al., *Co-Precipitation of Radium with Barium and Strontium Sulfate and Its Impact on the Fate of Radium During Treatment of Produced Water from Unconventional Gas Extraction*, 48 ENVTL. SCI. & TECH. 4596, 4596–603 (2014).

72. *Id*. at 4602.

73. Can He et al., *Co-Treatment of Abandoned Mine Drainage and Marcellus Shale Flowback Water for Use in Hydraulic Fracturing*, 104 WATER RES. 425, 425 (2016).

74. *Id.* at 429–431.

75. Warner et al., *supra* note 39, at 11,855.

76. Vearrier, *supra* note 46, at 400.

TENORM waste from oil and gas production is minimal.[77] In a recent report by the Pennsylvania Department of Environmental Protection (DEP), officials concluded that there is currently little or limited potential for radiation exposure to workers and the public.[78] The report further indicated potential for environmental and health impacts from specific exposure pathways, such as radium spills from oil and gas fluids during transport and storage; filter cakes with elevated TENORM from treatment of oil and gas waste; and the use of radium containing brines for dust suppression and road stabilization.[79] However, the Pennsylvania DEP report underlines the need to develop appropriate safety measures for worker protection, set limits for TENORM waste, implement policies for cleanup of radioactive spills, and review protocols for long-term TENORM waste disposal.[80]

In contrast, a recent Johns Hopkins study evaluated predictors of indoor air concentrations by investigating whether increases in radon levels were linked to unconventional drilling. They found an increase in drilling of unconventional wells that corresponded with an upward trend in radon levels in the basements of Pennsylvania homes.[81] The rising concern surrounding increased TENORM necessitates policies and regulations that coincide with the magnitude of the potential public health and environmental risks.

III. DISPOSAL OPTIONS FOR TENORM AND NORM

Safe and economical disposal methods need to be developed with the increased concentration of NORM and TENORM wastes, which include contaminated equipment, scale, sludge, drill cuttings, and produced water. TENORM may be concentrated because of:

(1) temperature and pressure changes during oil and gas production,
(2) 226Ra and 228Ra in produced waters reacting with barium sulfate (BaSO4) to form a scale in well tubulars and surface equipment,

---

77. *Id.* at 399.

78. PERMA-FIX ENVTL. SERV. INC., TECHNOLOGICALLY ENHANCED NATURALLY OCCURRING RADIOACTIVE MATERIALS (TENORM) STUDY REPORT 0-1(2006) [hereinafter Study Report].

79. *Id.* at 912.

80. *Compare* Study Report, *supra* note 78, at 0-1, *with* RESNIKOFF, *supra* note 44, at 18 (criticizing the DEP Study Report).

81. Casey et al., *supra* note 14, at 1136.

(3) 226Ra and 228Ra occurring in sludge that accumulates in pits and tanks, and
(4) NORM occurring as radon (Rn) gas in the natural gas stream.[82]

Historically, disposal options for oil and gas wastes are limited. These options include (1) injection or re-injection into regulated Class II disposal wells or plugged and abandoned wells;[83] (2) discharge of waste into surface waters;[84] (3) discharge in land via land spreading, burial, deposit in abandoned mines or tunnels, landfill dumping, and in open pits/ponds;[85] (4) equipment smelting without decontamination followed by recycling of the metal and disposal of the slag;[86] (5) minimization techniques including recent technologies such as gasification, oxidation-reduction-reaction chemicals, solid and fluid separation, and bioreactor cells;[87] and (6) salt dome disposal where TENORM wastes are injected and placed into old-abandoned-underground salt dome formations.[88]

The means of disposal is often dependent on the type of waste generated. For instance, flowback and produced water brought to the surface is often collected, first stored in on-site impoundments or tanks that are often lined with plastic sheeting to prevent leakage.[89] Later, flowback

82. Kargbo, *supra* note 17 at 5681.

83. Khalid ALNabhani et al., *Scenario-Based Risk Assessment of TENORM Waste Disposal Options in Oil and Gas Industry*, 40 J. LOSS PREVENTION IN THE PROCESS INDUSTRIES 55, 56 (2016).

84. *Id.*

85. *Id.*

86. *Id.* at 57.

87. *Id.*

88. *Id.*

89. *See*, *e.g*., Brown, *supra* note 13, at A52; *see also* Andrew N. Nelson et al., *Monitoring Radionucleotides in Subsurface Drinking Water Sources near Unconventional Drilling Operations: A Pilot Study*, 142 J. ENVTL. RADIOACTIVITY 24, 24 (2015) (listing various ways that NORM could contaminate groundwater). *See generally* Eric S. Eitrheim et al., *Disequilibrium of Naturally Occurring Radioactive Materials (NORM) in Drill Cuttings from a Horizontal Drilling Operation*, 3 ENVTL. SCI. & TECH. LETTERS 425, 425 (2016) (regarding solid waste from unconventional drilling); Andrew W. Nelson et al., *Partitioning of Naturally-Occurring Radionuclides (NORM) in Marcellus Shale Produced Fluids Influenced by Chemical Matrix*, 18 ENVTL. SCI. 456, 459 (2016) (describing the possibility for NORM to enter the surface through absorption or sedimentation); Lindsey Konkel, *What's NORMal for Fracking?: Estimating Total Radioactivity of Produced Fluid*s, ENVTL. HEALTH PERSP., July 2015, at A186, A186 (describing a study that tested how radionuclide concentrations change over time in wastewater); Andrew W. Nelson, Naturally Occurring Radioactive Materials Associated with Unconventional Drilling for Natural Gas 57 (Spring 2015) (unpublished Ph.D. dissertation, University of Iowa) (on file with Iowa Research Online, University of Iowa) (listing various ways that NORM could contaminate groundwater); M.A. Hilal et al., *Evaluation of Radiation Hazard Potential of TENORM Waste from Oil and Natural Gas Production*, 136 J. ENVTL. RADIOACTIVITY 121, 121 (2014) (listing water treatment and petroleum production as two of the main sources of TENORM); S. Landsberger et al., *Determination of* ^{226}*Ra,* ^{228}*Ra and* ^{210}*Pb in NORM Products from Oil and Gas Exploration: Problems in Activity Underestimation to the Presence of Metals and Self-Absorption of Photons*, 125 J. ENVTL. RADIOACTIVITY 23, 23 (2013) ("TENORM has also become

and produced water must be removed from the drill site and disposed of or recycled. Removal typically occurs through transport to a wastewater treatment plant, injection into underground wells, or re-purposing for non-oil and gas use such as watering of agricultural crops or de-icing.[90] After waste is sent to wastewater treatment plants, NORM or TENORM can accumulate as sludge and scale, and potentially serve as a source of long-term exposures if not removed from piping or contaminated equipment.[91] Treatment of these wastewaters can, however, further concentrate the waste streams containing radium.[92] In fact, researchers in Pennsylvania discovered treatment of these wastewaters has increased radioactive concentrations in surface waters.[93]

The use of TENORM waste as a road de-ice or dust suppressant, using drilling cuttings in road maintenance, and spreading liquids or sludge on fields, ultimately leading to additional radiological exposures is a controversial disposal option.[94] Consequently, some states now prohibit the disposal of radium-bearing NORM waste on public and private roads due to unnecessary radiation exposure.[95]

Other disposal options vary depending on the type of waste generated. Radium-bearing wastes, such as drill cuttings, scale, sludge, and muds may be disposed of in open pits or sent to solid waste landfills, which exposes workers and residents near these storage sites.[96]

If certain exemption limits mandate action, then the radium content of scale and sludge in the injected and re-injected water is often not regulated

---

a widely recognized problem in the oil and gas industry."); MCBURNEY, *supra* note 68, at 4 (providing the many options, including evaporation ponds, that the oil and gas industry has to dispose of NORM and TENORM waste); Hannah J. Wiseman, *Risk and Response in Fracturing Policy*, U. COLO. L. REV. 729, 773 (2013) (explaining the lack of clarity on "whether flowback water may be stored in an unlined pit or not and how it must be disposed of."). *But see* Terry Engelder, Comment, *Predictors of Indoor Radon Concentrations in Pennsylvania, 1989–2013*, ENVTL. HEALTH PERSP., Nov. 2015, at A273, A273 (2015) (finding significant sources of radon exposure other than fracking).

90. Daniel J. Price & Carl Adams, Jr., *Water Use and Wastewater Management*, *in* ENVIRONMENTAL AND HEALTH ISSUES IN UNCONVENTIONAL OIL AND GAS DEVELOPMENT 61–79 (Debra Kaden & Tracie Rose eds., 2016).

91. Walter et al., *supra* note 36, at 1040.

92. ASS'N OF STATE & TERRITORIAL SOLID WASTE MGMT. OFFICIALS, *supra* note 23, at 7.

93. William D. Burgos et al., *Watershed-Scale Impacts from Surface Water Disposal of Oil and Gas Wastewater in Western Pennsylvania*, 51 ENVTL. SCI. & TECH. 8851, 8858 (2017); Am. Chemical Soc'y, *Release of Treated Wastewater from Hydraulic Fracturing Contaminates Lake*, SCI. DAILY (July 12, 2017), https://www.sciencedaily.com/releases/2017/07/170712110605.htm [https://perma.cc/TH4F-JPRE?type=image].

94. ASS'N OF STATE & TERRITORIAL SOLID WASTE MGMT. OFFICIALS, BENEFICIAL USE OF DRILL CUTTINGS, PRODUCED WATER AND FLUIDS IN THE U.S. 4 (2017), http://astswmo.org/files/Resources/Materials_Management/OGWaste-Beneficial-Use-Followup-Report-11-29-17.pdf [https://perma.cc/5GP7-SUYJ].

95. 16 TEX. ADMIN. CODE § 4.611 (2003).

96. Walter et al., *supra* note 36, at 1040; Brown, *supra* note 13, at A52.

the same way as radium-bearing scale and sludge.[97] All options of TENORM waste disposal can cause potential radiological risk due to radium and radon emissions.[98] For instance, some samples have eight times the beta radiation than is set by EPA regulatory limits.[99]

The number of lawsuits from TENORM exposure is on the rise.[100] As recently as 2014, the Fifth Circuit Court of Appeals reversed the dismissal of claims by the survivors of deceased pipe yard workers on oilfields. The survivors claimed that exposure to TENORM bearing wastes led to a number of diseases, adverse health conditions, and death.[101] The link between TENORM exposure and specific health conditions was originally difficult to prove due to many of these conditions appearing later in life.[102] Additionally, exposure to low-level irradiation has not been proven to cause the cancer.[103]

IV. FEDERAL OVERSIGHT OF NORM AND TENORM

The natural environment contains background radiation of various concentrations, which makes regulating difficult.[104] There is currently no national regulatory policy or an established cut-off for safe radiation levels. To help guide regulatory discretion, the Conference of Radiation Control Program Directors (CRCPD) put forth "Suggested State Regulations for the Control of Radiation (SSRCRs) for NORM and TENORM."[105] The CRCPD has no legal authority over the regulation of TENORM or NORM, but some states chose to adopt these regulations, such as Ohio, Mississippi, and Virginia.[106] NORM-bearing wastes are not generally regulated under

---

97. Karen P. Smith et al., *Assessment of the Disposal of Radioactive Petroleum Industry Waste in Nonhazardous Landfills Using Risk-Based Modeling*, 37 ENVTL.SCI & TECH. 2060, 2060-61 (2003).

98. Brown, *supra* note 13, at A4.

99. *Id.*

100. *See generally* Coleman v. OFS, Inc., 771 F.3d 815, 816 (5th Cir. 2014) (noting an increase of litigants joining the class action after notification of their exposure to TENORM).

101. *Id.* at 818.

102. Khalid ALNabhani et al., *The Importance of Public Participation in Legislation of TENORM Risk Management in the Oil and Gas Industry*, PROCESS SAFETY AND ENVTL. PROTECTION 606, 609 (2016).

103. *Id.*

104. Rich & Crosby, *supra* note 33, at 128–31 (discussing federal regulatory oversight).

105. *Suggested State Regulations for Control of Radiation*, CONFERENCE OF RADIATION CONTROL PROGRAM DIRECTORS, http://www.crcpd.org/page/SSRCRs [https://perma.cc/5AUB-XTML] (last visited Feb. 4, 2018).

106. ASS'N OF STATE AND TERRITORIAL SOLID WASTE MGMT. OFFICIALS, STATE REGULATIONS AND POLICIES FOR CONTROL OF NATURALLY-OCCURRING AND ACCELERATOR PRODUCED RADIOACTIVE MATERIALS (NARM) AND TECHNOLOGICALLY ENHANCED NATURALLY

federal guidelines, but may be regulated under the U.S. Department of Transportation if the wastes are in excess of 2,000 pCi/g.[107]

The Atomic Energy Act of 1954 governs the operations of nuclear facilities and related activities; however, TENORM containing less than 0.05% uranium or thorium by weight, or any combination thereof, is not subject to regulatory control.[108] The U.S. Nuclear Regulatory Commission (NRC) has authority to regulate disposal of low-level radioactive waste.[109] However, TENORM is not governed by the Low Level Radioactive Waste Policy Act, which defines low-level radioactive waste (LLW) as material that: (i) is not a high-level radioactive waste, spent nuclear fuel, or byproduct material; and (ii) has been classified by the NRC as a LLW.[110]

TENORM wastes associated with oil and gas exploration and production may be categorized as special wastes and exempt from regulations under the Resource Conservation and Recovery Act's (RCRA) Subtitle C.[111] Federal regulatory exemptions for oil and gas depends on how the material was used or generated as waste. For example, if waste comes to the surface during exploration and production operations or generated by contact with the oil and gas production stream during the removal of produced water or other contaminants from the product, then the waste is exempt from Subtitle C as hazardous waste.[112] If, however, landfill sites created for chemically hazardous wastes under RCRA are used for TENORM waste disposal, then the wastes are subject to RCRA regulation.[113] Also, under provisions of the Safe Drinking Water Act, EPA regulates certain radioactive elements regarding their total radioactivity concentration of uranium, radium-226, and radium-228.[114]

OCCURRING RADIOACTIVE MATERIALS (TENORM) (2014), http://www.astswmo.org/Files/Policies_and_Publications/Materials_Management/State%20Statutes%20and%20Regulations%20on%20TENORM%20Final%20Dec2014.pdf [https://perma.cc/QK3R-YFQJ].

107. Rich & Crosby, *supra* note 33, at 128.

108. 42 U.S.C. §§ 2011–2259 (2012); *see* S.Y. Chen et al., *Toward the Framework and Implementation for Clearance of Materials from Regulated Facilities*, 89 HEALTH PHYSICS 115, 121 (2005) (discussing the difficulties of implementing SSRCRs).

109. 42 U.S.C. §§ 2011–2259 (2012).

110. Atomic Energy Act, 42 U.S.C. §§ 2021b–2021j (2012).

111. OFFICE OF SOLID WASTE, U.S. ENVTL. PROT. AGENCY, EXEMPTION OF OIL AND GAS EXPLORATION AND PRODUCTION WASTES FROM FEDERAL HAZARDOUS WASTE REGULATIONS 8 (2002), https://yosemite.epa.gov/oa/eab_web_docket.nsf/Attachments%20By%20ParentFilingId/945EF425FA4A9B4F85257E2800480C65/$FILE/28%20-%20RCRA%20E%26P%20Exemption.pdf [https://perma.cc/2QRP-BYRZ].

112. *Id.*

113. *Radionuclides in Drinking Water: Waste Disposal Options*, U.S. ENVTL. PROTECTION AGENCY, https://cfpub.epa.gov/safewater/radionuclides/radionuclides.cfm?action=Rad_Disposal%20Options [https://perma.cc/S87L-PA3P] (last visited Feb. 4, 2018).

114. *Id.*

American National Standards Institute and Health Physics Society created ANSI/HPS Standard N13.53-2009[115] that established consensus standards for disposal of TENORM wastes in solid or hazardous waste facilities. Based on these standards, the Association of State & Territorial Solid Waste Management Officials (ASTSWMO) set forth guidelines for TENORM waste disposal in solid waste facilities recommending a 25 millirems/year limit for exposure to the public.[116]

The Occupational Safety and Health Administration (OSHA) promulgated rules specific to occupational exposure to ionizing radiation, which may or may not apply to shale gas extraction.[117] OSHA governs general regulations for TENORM because of its role in advocating for worker's health and safety.[118] Seventeen states developed clearance levels and regulations for managing these materials under oil and gas provisions or waste disposal provisions.[119] Per the U.S. EIA, at least 21 states are producing 50 million cubic feet of natural gas or oil annually that are contributing to significant sources of NORM and TENORM.[120] Five states have provisions protecting workers that are expressly applied to oil and gas workers, while only three states include protections for the public.[121]

Through radiation control measures, it is the states' responsibility to regulate TENORM. States protect oil and gas and other downstream operations that are exposed to TENORM differently.[122] Thus, regulations for NORM and TENORM remain inconsistent across the country.[123]

V. NORM & TENORM REGULATION IN THE STATES

---

115. ASS'N OF STATE & TERRITORIAL SOLID WASTE MGMT. OFFICIALS, *supra* note 23, at 9.

116. *Id.* at 29.

117. 29 C.F.R § 1910.1096 (1998).

118. *Id.*

119. INT'L ATOMIC ENERGY AGENCY, REGULATORY AND MANAGEMENT APPROACHES FOR THE CONTROL OF ENVIRONMENTAL RESIDUES CONTAINING NATURALLY OCCURRING RADIOACTIVE MATERIAL (NORM), 61, 104–05 (2006), http://www-pub.iaea.org/MTCD/publications/PDF/te_1484_web.pdf [https://perma.cc/S5RU-79D9].

120. *See Natural Gas Gross Withdrawals*, U.S. ENERGY INFO. ADMIN., https://www.eia.gov/dnav/ng/ng_prod_sum_a_EPG0_FGW_mmcf_a.htm [https://perma.cc/VR24-N9HS] (last visited Feb. 4, 2018) (showing the gross withdrawal calculation includes oil well withdrawals and production).

121. GELTMAN & LECLAIR, *supra* note 50, at 2; *see* 16 TEX. ADMIN. CODE § 4.608 (2003) (providing protections to oil and gas employees); N.M. Code R. §§ 20.3.14.1405–06 (2001) (providing protections to both the public and employees); LA. ADMIN. CODE tit. 33, § 1411 (2009) (providing protections to employees); Miss. Code Ann. § 53-1-17 (providing protections to both the public and employees); 6 COLO. CODE REGS. § 1007-1 (providing protections to both the public and employees).

122. GELTMAN & LECLAIR, *supra* note 50, at 1–2.

123. Vearrier, *supra* note 46, at 404.

The number of active oil and gas wells in the U.S. has exponentially grown in the past decade because of technological advances that allow access to large shale oil and gas reserves. There are more than 1.7 million oil and gas wells drilled across 35 of the 50 states (70%) in the U.S. Although density varies widely, an estimated 1,673 out of 3,144 (53%) U.S. counties now have an oil or gas well.[124] The density of drilled wells per state ranges from 57 in Maryland to about 291,996 in Texas.[125] One hundred thirty-five counties have a single oil or gas well.[126] Texas has the greatest collective number of wells.[127] Kern County, California, has the most active wells in the U.S. with 77,497 oil and gas wells.[128]

Although EPA issued a general guidance memo in 2003,[129] regulation of TENORM and NORM is left to each oil and gas state.[130] Thus, many states have either chosen to include regulation of TENORM or NORM under general radiation provisions or to adopt regulations under oil and gas provisions.[131] Table 1 presents a summary of state approaches to regulating NORM and TENORM in the oil and gas industry presented by level of state activity, as of 2015.[132] Table 1 includes the authority where each state developed the protective measures, whether it be laws, regulations, guidance, or case-by-case permitting.[133]

124. Matt Kelso, *1.7 Million Wells in the U.S. – A 2015 Update*, FRACKER ALLIANCE: LATEST NEWS (Aug. 15, 2015), https://www.fractracker.org/2015/08/1-7-million-wells/ [https://perma.cc/L6DY-VHUT].

125. *Id.*

126. *Id.*

127. *Id.*

128. *Id.*

129. Memorandum from Frank Marcinowski, Dir., Radiation Prot. Div., on the Potential for Radiation Contamination Associated with Mineral and Res. Extraction Indus. to Regional Radiation Contacts (Apr. 15, 2003), https://www.epa.gov/sites/production/files/2015-04/documents/mineguide.pdf [https://perma.cc/794S-YJJJ].

130. ASS'N OF STATE & TERRITORIAL SOLID WASTE MGMT. OFFICIALS, *supra* note 106, at 2.

131. *Id*. at 2–3.

132. Kelso, *supra* note 124.

133. *Id.*

State	States Producing Oil & Gas	Number of Wells in State (as of 2015)	Agreement State[134]	General Radiation Provisions for TENORM or NORM	Oil and Gas Laws for TENORM or NORM or Laws for Disposal
TX		291,996	✓*	NORM*	✓
KS		252,097	✓*		✓
OK		206,373	✓*		
PA		136,036	✓*		✓
WV		109,747		TENORM	
CA		105,037	✓*		✓
CO		72,313	✓	Both	✓
IL		69,222	✓*		✓
WY		66,298			✓
LA		64,710	✓*	Both	✓
NM		60,943	✓	NORM*	✓

134. OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS, U.S. NUCLEAR REG. COMMISSION, *Directory of Agreement State and Non-Agreement State Directors and State Liaison Officers*, https://scp.nrc.gov/asdirectory.html [https://perma.cc/T7NQ-WR8Q] (last updated Feb. 6, 2018) ("Agreement States have entered into agreements with NRC that give [the state] the authority to license and inspect byproduct, source, or special nuclear materials used or possessed within [state] borders.").

			*		
KY	✓ 1	32,483	✓ *		✓
UT	✓ 1	27,352	✓ *		
NY	✓ 1	24,435	✓ *	NORM*	
MT	✓ 1	19,928			✓
MI	✓ 1	19,821			
AR		18,645	✓	NORM	
ND	✓ 1	17,931	✓ *	TENORM	✓
TN	✓ 1	15,814	✓ *		
VA	✓ 1	11,850	✓ *	Both	
AL		8,017			
MS	✓ 1	7,897	✓ *	Both	✓
IN	✓ 1	7,672			
MO		6,590			
AK		5,643			
NE	✓ 1	3,140	✓ *	TENORM	
OH	✓ 1	1,916	✓ *	both	✓

WA	✓ 0	721	✓ *		✓
SD	✓ 1	587			✓
OR	✓ 1	522	✓ *	NORM	
AZ	✓ 1	369			
NV	✓ 1	250	✓ *		
ID		152	✓ *		
FL	✓ 1	123	✓ *		
MD	✓ 1	57	✓ *		
CT		0			
DC		0			
DE		0			
GA		0	✓ *	Both	
HI		0			
IA		0	✓		
MA		0	✓ *	TENORM	
ME		0	✓ *		
MN		0	✓ *		

NC		0	✓		
RI		0	✓ *		
SC		0	✓ *	Both	
NH		0	✓ *		
NJ		0	✓ *	Both	
VT		0			
*NORM is used interchangeable to TENORM					

Table 2 summarizes the types of protections included in state oil and gas laws and regulations.

Oil & Gas Regulations							
State	**Worker Protection**	**Public Protections**	**Scale**	**Sludge**	**Produced water**	**Drill cuttings**	**Contaminated equipment**
TX	✓			✓	✓		✓
KS						✓	
OK							
PA				✓			✓
WV							✓

CA							
CO	✓	✓		✓			✓
IL						✓	
WY				✓			✓
LA	✓			✓			✓
NM	✓	✓		✓	✓		✓
KY							
UT							
NY							
MT					✓	✓	✓
MI							
AR				✓			✓
ND				✓			
TN							
VA							
AL							
MS	✓	✓		✓	✓		✓
IN							
MO							
AK							

NE							
OH							✓
WA							
SD							
OR							✓
AZ							
NV							
ID							
FL							
MD							
CT							
DC							
DE							
GA					✓		✓
HI							
IA							
MA							
ME							✓
MN							
NC							
RI							
SC							✓

NH							
NJ							
VT							
WI							

A. NORM & TENORM Regulation in States with Oil & Gas Drilling

Below is a state-by-state description of NORM and TENORM protections provided to oil and gas workers and the general public under respective state laws and policies.

1. Texas

Texas has a long history of oil and gas production. It also has one of the oldest and most robust oil and gas economies in the country.[135] In fact, Texas was the second state in the U.S. to pass legislative measures regarding oil refineries in 1899.[136] While the first sighting of oil in Texas was as far back as 1543, oil in Texas was not discovered or produced until the second half of the 19th century, and discovery and production has only increased with the advent of technologies.[137] As of 2015, Texas had 291,996 oil and gas wells drilled.[138] Significant drilling for natural gas occurs in all areas of the state in the five major formations.[139] Due to the

---

135. For discussion of unconventional oil and gas in Texas, see generally Jessica Schauwecker, *Defamation: Environmental Allegations Against Fracking Companies are Defamatory Per Se in Texas*, 69 SMU L. REV. 283 (2016) (discussing the history of defamatory environmental allegations against fracking companies in Texas); Alejandra C. Salinas, *Cleaning up the Colonias: Municipal Annexation and the Texas Fracking Boom*, 42 B.C. ENVTL. AFF. L. REV. 163, 163 (2015); Yong Eoh, *Yes, No, Maybe So: Uncertainty in Texas Groundwater Withdrawal for Hydraulic Fracturing*, 52 HOUS. L. REV. 1227, 1232–37 (2014) (discussing the history of hydraulic fracturing in Texas); Kirbie Watson, *The Emperor's New Clothes: Fracking Legislation in Texas*, 3 LSU J. ENERGY L. & RESOURCES 351 (2014) (explaining Texas's history of oil and gas production); Matthew Fry, *Urban Gas Drilling and Distance Ordinances in the Texas Barnett Shale*, 62 ENERGY POL'Y 79, 79 (2013); Dianne Rahm, *Regulating Hydraulic Fracturing in Shale Gas Plays: The Case of Texas*, 39 ENERGY POL'Y 2974, 2975 (2011).

136. Roger M. Olien, Oil and Gas Industry, TEX. ST. HIST. ASS'N, https://tshaonline.org/handbook/online/articles/doogz [https://perma.cc/6MKX-KMLU] (last modified Aug. 19, 2016); Kelso, *supra* note 124.

137. Rahm, *supra* note 135, at 2978.

138. Kelso, *supra* note 124.

139. Rahm, *supra* note 135, at 2975.

significant amount of oil and gas production, Texas has some of the most comprehensive laws and regulations in the country.[140]

The Barnett Shale covers 5,000 square miles and is considered the largest onshore natural gas formation in the U.S.[141] Mitchell Energy used new drilling technologies to realize the Barnett Shale's full potential.[142] The Eagle Ford Shale is 50 miles wide and 400 miles long; it has been a significant source of both gas and oil production ever since Petrohawk drilled its first wells in 2008.[143] Since 1993, the Granite Wash, located in the Texas Panhandle and Western Oklahoma, has produced 17.2 million barrels of oil and roughly 1.4 billion MCF of natural gas, with production only increasing in the last decade.[144] The Haynesville/Bossier Shale is a geological formation that can deliver large amounts of gas, becoming one of the major sources of natural gas.[145] Lastly, the Permian Basin is an oil and gas producing area located in West Texas and the adjoining area of Southeastern New Mexico.[146] The Permian Basin covers an area approximately 250 miles wide and 300 miles long; it remains a significant oil producing area producing more than 270 million barrels of oil in 2010 and more than 280 million barrels in 2011.[147]

Texas has regulated NORM under general radiation provisions since 1999; however, the provisions are not intended to regulate the disposal of NORM from oil and gas exploration.[148] Texas's long history of oil and gas production prompted the State to draft additional legislation aimed specifically at oil and gas NORM, which falls under the jurisdiction of the

---

140. *See generally* Olien, *supra* note 136 (discussing the history of Texas's oil and gas industry).

141. *Barnett Shale Information*, R.R. COMM'N OF TEX., http://www.rrc.state.tx.us/oil-gas/major-oil-and-gas-formations/barnett-shale-information/ [https://perma.cc/3A8Z-NQVR] (last updated Jan. 17, 2018).

142. *Id.*

143. *Eagle Ford Shale Information*, R.R. COMM'N OF TEX., http://www.rrc.state.tx.us/oil-gas/major-oil-and-gas-formations/eagle-ford-shale-information/ [https://perma.cc/BT6B-BDNT] (last updated Jan. 17, 2018).

144. *Granite Wash Information*, R.R. COMM'N OF TEX., http://www.rrc.state.tx.us/oil-gas/major-oil-and-gas-formations/granite-wash-information/ [https://perma.cc/A6TH-A4M4] (last updated Jan. 17, 2018).

145. *Haynesville/Bossier Shale Information*, R.R COMM'N OF TEX., http://www.rrc.state.tx.us/oil-gas/major-oil-and-gas-formations/haynesvillebossier-shale-information/ [https://perma.cc/G257-CHQJ] (last updated Jan. 17, 2018).

146. *Permian Basin*, R.R. COMM'N OF TEX., http://www.rrc.state.tx.us/oil-gas/major-oil-and-gas-formations/permian-basin-information/ [https://perma.cc/W4HN-KKU9] (last updated Jan. 17, 2018).

147. *Id.*

148. 45 TEX. ADMIN. CODE § 289.259 (1999).

Railroad Commission of Texas (RRC).[149] While these regulations do not supersede the general radiation provisions concerning NORM, they go further to address the radioactivity in oil and gas waste that presents new challenges.[150] In fact, Texas agencies have memoranda between them to "delineate areas of respective jurisdiction and to coordinate the respective responsibilities and duties of the DSHS and the RRC in the regulation of sources of radiation in accordance with Texas Health and Safety Code (HSC)."[151]

Texas uses the term NORM instead of TENORM, under both the general radiation provisions[152] and oil and gas NORM disposal provisions.[153] Texas defines NORM as "[n]aturally occurring [radioactive] materials not regulated under the AEA whose radionuclide concentrations have been increased by or as a result of human practices," which often meets the definition of TENORM.[154] Oil and gas NORM waste disposal limits for Ra-226 or Ra-228 are 30 pCi/g or less or 150 pCi/g of any other NORM radionuclide,[155] set forth under licensing requirements for NORM.[156] Pipes and other equipment used in oil production contaminated with NORM scale or residue should not exceed 50 microroentgen/hour (μR/hr).[157]

The RRC further regulates the disposal of NORM-bearing wastes in oil and gas operations.[158] Worker protections must be in place during the handling of NORM-bearing wastes and must adhere to provisions set out in the general licensure of NORM.[159] Produced water, which is considered NORM, is exempt from the requirements of these regulations, subject to regulations involving Class II injection wells.[160] Authorized disposal methods of NORM, which includes scale, sludge, and contaminated

149. DAVID PORTER, R.R. COMM'N OF TEX., EAGLE FORD SHALE TASK FORCE REPORT 2 (2013), https://cryptome.org/2015/01/eagle-ford-task-force-report.pdf [https://perma.cc/F9QV-F8SB].

150. *See generally* 16 TEX. ADMIN. CODE § 4.635 (2012) (discussing the areas and responsibilities of Texas's Railroad Commission and Department of State Health Services).

151. *Id.*

152. 45 TEX. ADMIN. CODE § 289.259(c)(4) (1999).

153. 16 TEX. ADMIN. CODE § 4.603 (2003).

154. 45 TEX. ADMIN. CODE § 289.259(c)(4) (1999).

155. 16 TEX. ADMIN. CODE § 4.603 (2003).

156. *Barnett Shale Information*, *supra* note 141.

157. 45 TEX. ADMIN. CODE § 289.259(d)(1)(A)(i-ii) (1999).

158. 16 TEX. ADMIN. CODE § 4.601(2003).

159. 16 TEX. ADMIN. CODE § 4.608 (2003).

160. U.S. GOV'T ACCOUNTABILITY OFFICE, GAO-14-555, EPA PROGRAM TO PROTECT UNDERGROUND SOURCES FROM INJECTION OF FLUIDS ASSOCIATED WITH OIL AND GAS PRODUCTION NEEDS IMPROVEMENT 1 (2014), http://www.gao.gov/assets/670/664499.pdf [https://perma.cc/JZ87-TCQU].

equipment, are outlined and detailed.[161] The following methods are included: disposal in plugged and abandoned wells, burial, land farming, disposal at a licensed facility, and deep well injection (pre-treated).[162] Texas prohibits the release of NORM-bearing and TENORM-bearing wastes into surface and subsurface waters.[163] In addition, Texas prohibits the disposal of NORM-bearing wastes on public or private roads.[164]

2. Kansas

Oil was first discovered in Neodesha, Kansas, on November 28, 1892.[165] Since that time, more than 350,000 wells have been drilled yielding more than five billion barrels of oil.[166] The first experimental hydraulic fracturing treatment in the U.S. took place in 1947 in the Hugoton Gas Field in Grant County, Kansas.[167] Since that first well, 252,097 wells have been hydraulically fractured as of 2015.[168]

While Kansas is an agreement state, it does not have specific licensure provisions for TENORM or NORM.[169] Rather, both TENORM and NORM are defined in solid waste management regulations and general radiation provisions.[170] Specific to oil and gas, Kansas allows land-spreading of NORM waste up to 10 pCi/g.[171] In this context, drill cuttings are considered NORM, and if the NORM level is more than the standard land-spreading must be stopped.[172] Further, Kansas established certain exemptions for permit requirements for disposal "of solid waste generated by drilling oil and gas wells by land-spreading in accordance with best management

---

161. 16 TEX. ADMIN. CODE § 4.614 (2003).
162. *Id.*
163. 16 TEX. ADMIN. CODE § 4.611 (2003).
164. *Id.*
165. Kan. Historical Soc'y, *Norman No. 1, Neodesha, Wilson County*, KANSAPEDIA, https://www.kshs.org/kansapedia/norman-no-1-neodesha-wilson-county/12159 [https://perma.cc/362Y-X7PB] (last modified Nov. 2010).
166. Kelso, *supra* note 124.
167. *See* DANIEL R. SUCHY & K. DAVID NEWELL, PUBLIC INFORMATION CIRCULAR 32: HYDRAULIC FRACTURING OF OIL AND GAS WELLS IN KANSAS 1 (2012), http://www.kgs.ku.edu/Publications/PIC/PIC32r1.pdf [https://perma.cc/9ZXB-9597] (discussing information about hydraulic fracking of oil and gas wells).
168. *Id.*
169. OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS, U.S. NUCLEAR REG. COMMISSION, *supra* note 134.
170. KAN. STAT. ANN. § 65-3402 (2016); KAN. STAT. ANN. § 48-1603 (2015); KAN. STAT. ANN. § 65-3402 (2015).
171. KAN. ADMIN. REGS. § 28-29-1604 (2013).
172. *See id.* (outlining the standards in Kansas for land spreading for the drilling waste and disposal site).

practices and maximum loading rates established in rules and regulations adopted by the secretary."[173]

Unlike Texas, the Kansas regulations do not address radioactivity of produced water, scale, sludge, or contaminated equipment. Given the rise in natural gas production, Kansas does not sufficiently address TENORM or NORM wastes.

3. Oklahoma

Oil was first discovered in Oklahoma in the late 1880s, and production of oil increased until about 1967 with estimates of 14.5 billion barrels in total.[174] Oklahoma remained the top oil-production state in the U.S. until 1923.[175] Oklahoma sits on the Caney and Woodford shale formations. As of 2015, Oklahoma is the state with the third highest number of wells in the U.S. with an estimated 206,373 wells drilled.[176]

In recent years, Oklahoma saw a notable rise in the number of earthquakes.[177] The increase in seismic activity in Oklahoma has attracted national attention—with many calling for increased regulatory action to reduce seismic impacts on Oklahoma residents. In an effort to regulate the industry, Oklahoma has taken measures to require disclosure of chemicals used in the fracturing fluid.[178] These measures require disclosure within 60 days either directly to the Chemical Disclosure Registry on FracFocus or

---

173. KAN. STAT. ANN. § 65-3407c (a)(8)(A) (2015).

174. *Historical Oklahoma Fracking Information*, BALLOTPEDIA, https://ballotpedia.org/Historical_Oklahoma_fracking_information [https://perma.cc/2QJA-4EWV] (last visited Feb. 3, 2018).

175. Dan T. Boyd, *Oklahoma Oil: Past, Present, and Future*, 62 OKLA. GEOLOGY NOTES 97, 98 (2002).

176. Kelso, *supra* note 124.

177 . Laura Bergedieck, *Shaky Ground: How the Disposal of Wastewater from Oil Production Increases the Risk of Earthquakes in Oklahoma*, CHI. POL'Y REV., (Aug. 31, 2016), http://chicagopolicyreview.org/2016/08/31/shaky-ground-how-the-disposal-ofwastewater-from-oil-production-increasesthe-risk-of-earthquakes-in-oklahoma/ [https://perma.cc/X62D-WYJN]; Shondricka Burrell et al., *Evaluating the Connections Between Fracking and Earthquakes*, 32 EARTH SCIENTIST at 23, 26–27 (2016); Emily LaGarenne, The Spatial Pattern of Hydraulic Fracturing-Induced Seismicity in Central Oklahoma 1 (Apr. 2015) (unpublished senior thesis, University of Louisville) (on file with author); Carolyn Rice, *The Struggle for Shared Governance in Hydraulic Fracking Policy: An Interstate Comparison of Texas, Oklahoma, and Colorado* (Ctr. for Loc., St., and Urb. Pol'y, Working Paper No. 2, 2016), http://closup.umich.edu/student-working-papers/2/the-struggle-for-shared-governance-in-hydraulic-fracturing-policy-an-interstate-comparison-of-texas-oklahoma-and-colorado/ [https://perma.cc/3EXK-FW3B].

178. OKLA. ADMIN. CODE. § 165:10-3-10(c) (2017).

indirectly to the Oklahoma Corporation Commission.[179] Companies, however, can claim exemptions if the chemical formulas are trade secrets.[180] Such exemptions allow for loopholes and may be contributing to overexposures to chemicals and radioactive elements. Despite the call for increased regulatory action, the desire for increased state oil and gas regulation is not universal. Oklahoma lawmakers sought to ban communities from issuing local bans on fracking in response to the rise in earthquakes.[181]

Although Oklahoma is an agreement state, neither the general radiation provisions nor the oil and gas provisions expressly license TENORM or NORM. While Oklahoma is a major oil and gas producer, Oklahoma laws governing the oil and gas industry as well as general radiation provisions lack regulatory framework regarding TENORM and NORM waste.

4. Pennsylvania

Pennsylvania has 136,036 drilling wells.[182] Pennsylvania also has one of the largest shale formations in the country—the Marcellus Shale.[183] The Marcellus Shale is estimated to contain 10 to 100 parts per million (ppm) of uranium, whereas other areas in the U.S. average only 3 ppm. Oil and gas exploration began in the Marcellus Shale in earnest in 2003.[184]

---

179. *Id.*

180. Paul Monies, *New Rules Approved by Oklahoma Corporation Commission Will Require Disclosure of Hydraulic Fracturing Chemicals in State*, NEWSOK (Mar. 21, 2012, 12:00 A.M.), http://newsok.com/article/3659437 [https://perma.cc/SJ8P-94SB].

181. Oklahoma and Fracking, EARTHJUSTICE, http://earthjustice.org/features/oklahoma-and-fracking [https://perma.cc/NT7K-ALP8] (last visited Feb. 3, 2018). For a discussion of public opinion about fracking in Pennsylvania, see Erica Brown et al., *The National Surveys on Energy and Environment Public Opinion on Fracking: Perspectives from Michigan and Pennsylvania*, 3 ISSUES IN ENERGY & ENVTL POL'Y 1, 1–26 (May 2013), *available at* http://closup.umich.edu/issues-in-energy-and-environmental-policy/3/public-opinion-on-fracking-perspectives-from-michigan-and-pennsylvania/[https://perma.cc/Q5SJ-KFNY]. For a discussion of health concerns, see generally Qingmin Meng, *Spatial Analysis of Environment and Population at Risk of Natural Gas Fracking in the State of Pennsylvania, USA*, 515–16 SCI. TOTAL ENVTL. 198 (2015) (discussing health concerns from high-volume fracking).

182. Kelso, *supra* note 124.

183. Barry G. Rabe & Christopher Borick, *Conventional Politics for Unconventional Drilling? Lessons from Pennsylvania's Early Move into Fracking Policy Development*, 30 REV. POL'Y RES. 321, 324 (2013); Michael H. Finewood & Laura J. Stroup, *Fracking and the Neoliberalization of the Hydro-Social Cycle in Pennsylvania's Marcellus Shale*, 147 J. CONTEMP. WATER RES. & EDUC. 72, 75 (2012); *see, e.g.*, Brendan M. Cosgrove et al., *The Economic Impact of Shale Gas Development: A Natural Experiment along the New York/Pennsylvania Border*, 44 AGRIC. & RES. ECON. REV. 20, 21 (2015) (discussing the impacts of fracking on employment).

184. *Potential Development of the Natural Gas Resources in the Marcellus Shale*, U.S. DEP'T INTERIOR, https://www.nps.gov/frhi/learn/management/upload/grd-m-shale_12-11-2008_high_res.pdf [https://perma.cc/YTE7-N3UT] (last visited Feb. 3, 2018).

Pennsylvania is one of the fastest growing areas for hydraulic fracturing. Given the high uranium content of the Marcellus Shale, the potential for radiological exposure to TENORM-generated wastes during shale gas extraction is particularly problematic.[185] To deal with the wastes, Pennsylvania employs a number of techniques, including treatment of flowback and produced water and subsequent release into state surface waters.[186] An estimated 1,210 million gallons per day of water from lakes, rivers, and streams are withdrawn in Pennsylvania for public supply.[187] Furthermore, as many as 8 million people rely on drinking water from streams alone.[188]

To facilitate monitoring radioactivity in waste, the Pennsylvania DEP issued a guidance document pursuant to the Pennsylvania Solid Waste Management Act, the Radiation Protection Act, and specific provisions of the Pennsylvania Administrative Code that define NORM and TENORM.[189] Workers and the public are protected by general radiation provisions, but they are not expressly covered for NORM and TENORM in oil and gas operations. However, Pennsylvania does require radiation testing at landfills under the solid waste regulations, thus serving as some protection for nearby residents and workers at landfills from TENORM waste.[190]

In 2013, the Pennsylvania DEP conducted a study in response to the large amount of TENORM waste generated during shale gas extraction.[191] The DEP study assessed worker and public exposures from TENORM waste generation, disposal, and reuse on roads as a dust suppressor or road stabilizer.[192] The DEP concluded that there was little potential for harm to workers or the public from radiation exposure due to oil and gas drilling.[193]

---

185. Brown, *supra* note 13, at A52.

186. *Id.* at 5.

187. JOAN F. KENNY ET AL., ESTIMATED USE OF WATER IN THE UNITED STATES IN 2005 16 (U.S. Geological Survey Circular, 1344, 2005), https://pubs.usgs.gov/circ/1344/pdf/c1344.pdf [https://perma.cc/JH9N-X99P].

188. *Geographic Information Systems Analysis of the Surface Drinking Water Provided by Intermittent, Ephemeral, and Headwater Streams in the U.S.*, U.S. ENVTL. PROTECTION AGENCY, https://www.epa.gov/sites/production/files/2015-06/documents/2009_12_29_wetlands_science_surface_drinking_water_surface_drinking_water_pa.pdf [https://perma.cc/LE4G-J7KD] (last visited Feb. 3, 2018).

189. PA. DEP'T OF ENVTL. PROT., FINAL GUIDANCE DOCUMENT OF RADIOACTIVITY MONITORING AT SOLID WASTE PROCESSING AND DISPOSAL FACILITIES 1–37 (2004), http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-48337/250-3100-001.pdf [https://perma.cc/HVS8-J3CV].

190. *Id.*

191. Study Report, *supra* note 78, at 0–1.

192. *Id.*

193. *Id.*

This study served as a check on existing oil and gas TENORM regulations and led the State to conclude that no additional protective regulation was needed.[194] The study did conclude that there is potential exposure to radiation from treatment of oil and gas wastes and spills.[195] Thus, the DEP should incorporate protocols during site characterization and should evaluate and implement work protections to address these concerns.[196]

5. West Virginia

The West Virginia portion of the Marcellus Shale has an estimated 109,747 oil and gas wells,[197] including 29 wells operated in the Gauley River and New River Gorge National River.[198] While West Virginia is not an agreement state, TENORM is licensed under general radiation provisions, which also include contaminated equipment.[199] The exemption limit for TENORM waste is 5 pCi/g for Ra-226 and Ra-228.[200] The West Virginian regulatory guidelines are consistent with many other states operating with the same number of wells.

6. California

California has an estimated 105,037 wells,[201] and the industry contributes 9% to the State's GDP.[202] In California, hydraulic fracturing has occurred since the 1980s. Production on many of the formations in California occurs via vertical wells into conventional oil and natural gas

---

194. *Id.*
195. *Id.*
196. *Id.* at 9-13.
197. Kelso, *supra* note 124. For a discussion of fracking in West Virginia, see generally Joshua P. Fershee, *The Oil and Gas Evolution: Learning from the Hydraulic Fracturing Experiences in North Dakota and West Virginia* 19 TEX. WESLEYAN L. REV. 23, 24 (2012) (discussing fracking in West Virginia); *see also* Mary Beth Adams, *Land Application of Hydrofracturing Fluids Damages a Deciduous Forest Sand in West Virginia*, 40 J. ENVTL. QUALITY 1340, 1340–44 (2011) (discussing the environmental effects of hydraulic fracturing); *see also* HIGGINBOTHAM ET AL., WEST VIRGINIA UNIV., THE ECONOMIC IMPACT OF THE NATURAL GAS INDUSTRY AND THE MARCELLUS SHALE DEVELOPMENT IN WEST VIRGINIA IN 2009 1 (2010) (analyzing the economic gains from the gas industry in West Virginia).
198. Geltman, *supra* note 22, at 157–58 (discussing framework on 9B Regulations governing oil and gas drilling in national parks).
199. W. VA. CODE § 64-23-16 (2001).
200. W. VA. CODE § 64-23-16.4.a (2001).
201. Kelso, *supra* note 124.
202. *California and Fracking*, EARTHJUSTICE, https://earthjustice.org/features/california-and-fracking [https://perma.cc/QY5C-WXEL] (last visited Feb. 3, 2018).

reserves.[203] While there are protection standards in place for well operations, California has not enacted legislation regarding TENORM waste generated during these operations.[204] A RCRA hazardous waste facility in California, however, is permitted to take up to 1,800 pCi/g TENORM and NORM waste in the U-238, U-235, and Th-232 decay series.[205]

7. Colorado

Colorado has an estimated 72,313 wells.[206] The first oil well was drilled in the Pierre Shale Formation in 1901, and large-scale fracking occurred in Colorado as early as 1973.[207] Colorado has four shale formations within its borders: the Niobrara Shale Formation, Green River Formation, Sand Wash Basin, and Wattenberg Gas Field.[208] The Wattenberg Gas Field is responsible for much of the natural gas play in Colorado, with estimates that it holds 5.2 trillion cubic feet of gas.[209] As of 2014, Colorado produced

---

203. *Hydraulic Fracturing in California*, CA. DEP'T CONSERVATION, http://www.conservation.ca.gov/dog/general_information/pages/Hydraulicfracturing.aspx [https://perma.cc/UJW8-N4L2] (last visited Feb. 3, 2018).

204. *Id.*

205. MIKE HALL, TENORM: MANAGEMENT & DISPOSAL 13 (2014), http://serc.osu.edu/files/management-disposal.pdf [https://perma.cc/BWU2-J3BQ].

206. Kelso, *supra* note 124.

207. *Historical Colorado Fracking Information*, BALLOTPEDIA, https://ballotpedia.org/Historical_Colorado_fracking_information [https://perma.cc/8879-22K3] (last visited Feb. 3, 2018); *see also* Jeffrey J. Cook, *Who's Pulling the Fracking Strings? Power, Collaboration and Colorado Fracking Policy*, 25 ENVTL. POL'Y & GOVERNANCE 373, 373–85 (2015) (discussing a new approach to policy making). *See generally* Joel Minor, *Local Government Fracking Regulation: A Colorado Case Study*, 33 STAN. ENVTL. L.J. 59, 59–61 (2014) (discussing fracking regulation in Colorado); RICHARD WOBBEKIND & BRIAN LEWANDOWSKI,HYDRAULIC FRACTURING BAN: THE ECONOMIC IMPACT OF A STATEWIDE FRACKING BAN IN COLORADO 7 (Cindy DiPersio ed., 2014) (discussing the development of hydraulic fracturing in Colorado); Tanya Heikkila et al., *Understanding a Period of Policy Change: The Case of Hydraulic Fracturing Disclosure Policy in Colorado*, 31 REV. POL'Y RES. 65, 65–87 (2014) (analyzing the promulgation of Colorado regulations that required disclosure of chemicals used in hydraulic fracking); Charles Davis, *The Politics of "Fracking": Regulating Natural Gas Drilling Practices in Colorado and Texas*, 29 REV. POL'Y RES. 177, 185 (2012) ("Colorado has numerous wells distributed widely throughout the state."); Abraham Lustgarten, *Colorado Study Links Methane in Water to Drilling*, PROPUBLICA (Apr. 22, 2009, 6:00 AM), https://www.propublica.org/article/colorado-study-links-methane-in-water-drilling-422/ [https://perma.cc/2SN7-NWD4] (outlining concerns of methane contamination from drilling).

208. *Id. See generally* Lisa M. McKenzie et al., *Birth Outcomes and Maternal Residential Proximity to Natural Gas Development in Rural Colorado*, 122 ENVTL. HEALTH PERSP. 412 (2014) (discussing birth outcomes studied in Colorado).

209. Gargi Chakrabarty & Todd Hartman, *Wattenberg Field - A Bottomless Well?*, Rocky Mountain News (Oct. 18, 2008, 12:05 AM), http://archive.is/E8n5p [https://perma.cc/8U9W-3SMT].

more than 82.8 million barrels of crude oil.[210] Disposal of wastes generated during oil and gas operations has gained recent attention as lawsuits aimed at enacting local bans on fracking or banning disposal of wastes in communities are filed.[211]

Regulated disposal of TENORM and NORM occurs in the Deer Trail Landfill in Colorado. The landfill is a RCRA Subtitle C facility accepting up to 2,000 pCi/g of TENORM or NORM waste.[212] Given the large amounts of TENORM waste that is accepted at this facility, it is becoming a major acceptor of oil and gas wastes in the region.[213] Overall, the regulation of radioactive material in Colorado is the responsibility of the Radiation Control Program (RCP) of the Hazardous Materials and Waste Management Division (HMWMD). The authority to regulate TENORM is found in the general provisions of the Radiation Control Act and the Colorado Rules and Regulations pertaining to radiation control, both of which define TENORM and NORM.[214] Sludge, scale, and contaminated equipment are all considered TENORM under Colorado law.[215]

Colorado is developing final guidance pertaining to the disposal of TENORM waste that may be applicable to oil and gas operations.[216] The proposed standards would restrict the disposal of Ra-226 and Ra-228 in excess of 3 pCi/g in municipal solid waste landfills and 50 pCi/g in industrial landfills.[217] Guidance was originally meant to address TENORM

---

210. Mary Schaper, *Colorado Smashes Record for Oil Production*, ENERGY TOMORROW (Mar. 6, 2005), http://www.energytomorrow.org/blog/2015/03/06/us-energy-and-policy-choices [https://perma.cc/MC9D-NVW3].

211. Colorado Oil and Gas Ass'n v. Longmont, No. 13-CV-63, slip op. at 2 (Colo. Dist. Ct. July 24, 2014); *see also* James Burkhart et al., Symposium, *Potential Radon Release During Fracking in Colorado*, AMER. ASS'N OF RADON SCIENTISTS AND TECHNOLOGISTS, 20 (2013) (discussing evidence showing the leak of toxic substances in Colorado where fracking takes place).

212. *See* W.E. Kennedy Jr. et al., *Regulated Disposal of NORM/TENORM Waste in Colorado: The Deer Trail Landfill*, 2006 WASTE MGMT. SYMPOSIUM, http://www.wmsym.org/archives/2006/pdfs/6464.pdf [https://perma.cc/29YL-SFFK] (discussing a license for the disposal of NORM and TENORM at Clean Harbor's Deer Trail RCRA Subtitle C landfill).

213. W. ORG. OF RES. COUNCILS, NO TIME TO WASTE: EFFECTIVE MANAGEMENT OF OIL & GAS FIELD RADIOACTIVE WASTE 15, http://notimetowastereport.org/nttw-letter.pdf [https://perma.cc/AHC9-B8WY].

214. COLO. REV. STAT. §§ 25-11-101(2.7), 25-11-201(1)(f) (2001); 6 COLO. CODE REGS. § 1007-1 (2016).

215. *See* COLO. REV. STAT. § 25-11-201(2)(a)(II) (2001) (suggesting sludges, soils, and equipment are TENORM).

216. COLO. DEP'T HEALTH & ENV'T, TENORM Policy and Guidance Draft, (July 2014), https://www.colorado.gov/pacific/sites/default/files/HM_tenorm-policy-revisiondraft-080514.pdf.

217. *See* COLO. DEP'T OF PUBLIC HEALTH & ENV'T, INTERIM POLICY AND GUIDANCE FOR PENDING RULEMAKING FOR CONTROL AND DISPOSITION OF TECHNOLOGICALLY-ENHANCED NATURALLY OCCURRING RADIOACTIVE MATERIALS IN COLORADO (Feb. 2007),

generated from the treatment of drinking water; thus, the guidance may loosely apply to TENORM generated during oil and gas operations.[218] Regardless, the guidance outlines various disposal options as well as worker and public protections—serving as a basis for the development of protections.[219]

8. Illinois

Illinois has an estimated 69,222 wells.[220] Oil and gas production first occurred in the Illinois Basin in 1853, which is the third largest in the United States. Since 1853, Illinois produced approximately four billion barrels of oil and four trillion cubic feet of natural gas.[221] While production fell following World War II, increased drilling was economically possible due to advancements in drilling technologies.[222] Regulations pertaining to wastes that are generated during these drilling operations are addressed to some extent in oil and gas provisions of the Hydraulic Fracturing Regulatory Act.[223] The Act defines both TENORM and NORM[224] and addresses drill cuttings in the drilling mud but not in terms of its radioactivity.[225] Furthermore, Illinois outlines permit requirements for flowback and other fluids brought to the surface with hydraulic fracturing and specifies disposal in Class II injection wells. However, the law lacks specificity to the flowback's radioactivity.[226] The State prohibits the "unlawful [] inject[ion] or discharge [of] hydraulic fracturing fluid,

---

https://www.colorado.gov/pacific/sites/def ault/files/HM_tenorm-Interim-Policy-andGuidance-Pending-Rulemaking-for- Control-and-Disposition-ofTechnologically-Enhanced-NaturallyOccurring-Radioactive-Materials-inColorado_0.pdf (last visited Oct. 17, 2017) (illustrating the different proposed standards in municipal solid waste landfills and industrial landfills).

218. W. ORG. OF RES. COUNCILS, *supra* note 213, at 10.

219. *Id.*

220. Kelso, *supra* note 124. *See generally* Jennifer Cassel, *Illinois's Hydraulic Fracturing Regulatory Act: A Successful Compromise,* 49 J. MARSHALL L. REV. 315 (2015) (discussing the history of Illinois's 2013 Hydraulic Fracturing Regulatory Act and the current status of fracking in Illinois); John Abendroth, Comment, *Fracking in Illinois: Implementation of the Hydraulic Fracturing Regulatory Act and Local Government Regulatory Authority*, 35 N. ILL. U. L. REV. 575, 578–81 (2014) (providing background on fracking in Illinois); Dave Bieneman, *The Fracking Industry and Its Potential Impact on the Illinois Economy*, 33 ILL. LABOR MARKET REV. 1, 1–2 (2013) (discussing the development of horizontal drilling and explaining its economic impact).

221. Keith Shaefer, *Illinois Basin's New Albany Shale: The Next Big U.S. Horizontal Oil Play?*, OIL & GAS INV. BULL. (Sept. 23, 2013), https://oilandgas-investments.com/2013/oil-and-gas-financial/illinois-new-albany-shale-oil/ [https://perma.cc/KTQ2-Z5B7].

222. Bieneman, *supra* note 220, at 1–2.

223. *Id*.

224. ILL. ADMIN. CODE tit. 62, § 245.110 (2014).

225. *Id.* tit. 62, § 245.510.

226. *Id.* tit. 62, § 245.210.

produced water, BTEX, diesel, or petroleum distillates into fresh water (Section 1-25(c) of the Act)."[227]

Illinois allows for water treatment residuals and sewage treatment sludge, with total radium concentrations of 200 pCi/g or less, to be disposed of at a landfill.[228] This limit is not, however, explicit to TENORM or NORM in the oil and gas industry.[229] TENORM is also addressed in the compact between Illinois and Kentucky in the Central Midwest Interstate Low-Level Radioactive Waste Commission, which categorizes NORM, NARM, and TENORM as low-level radioactive waste (LLRW).[230] The State limits the disposal at LLRW facilities of 2,000 pCi/g of TENORM waste and prohibits import of TENORM waste with concentrations equal to or greater than 5 pCi/g.[231]

9. Wyoming

Wyoming has an estimated 66,298 wells.[232] Much of the activity occurs in the Powder River Basin, where 22 of the 23 counties produce natural gas.[233] A recent study found that fracking waste had a negative impact on water supplies in Wyoming.[234]

Wyoming is a letter of intent state.[235] Wyoming developed guidance for NORM and TENORM disposal under their solid and hazardous waste division, which is under the jurisdiction of the Wyoming Department of Environmental Quality.[236] NORM is defined as "any waste material exceeding the greater of natural background levels found in nearest non-

---

227. *Id.* tit. 62, § 245.630.

228. ILL. ADMIN. CODE tit. 32, § 330.40 (2015).

229. *Id.*

230. CENT. MIDWEST INTERSTATE & LOW-LEVEL RADIOACTIVE WASTE COMM'N, REGIONAL MANAGEMENT PLAN 28 (1999), https://www.illinois.gov/iema/info/Documents/cmccplan.pdf [https://perma.cc/ZF6Y-JT9X].

231. *Id.*

232. Kelso, *supra* note 124.

233. *See Wyoming State Profile 2016*, BALLOTPEDIA, https://ballotpedia.org/Wyoming_state_profile_2016 [https://perma.cc/S242-SZUU] (last visited Feb. 4, 2018) (explaining the significance of the Powder River Basin).

234. Dominic C. DiGiulio & Robert B. Jackson, *Impact to Underground Sources of Drinking Water and Domestic Wells from Production Well Stimulation and Completion Practices in the Pavilion, Wyoming, Field*, 50 ENVTL. SCI. & TECH. (2016).

235. OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS, U.S. NUCLEAR REG. COMMISSION, *supra* note 134.

236. WYOMING DEP'T OF ENVTL. QUALITY, GUIDELINE #24 NATURALLY OCCURRING RADIOACTIVE MATERIAL (NORM) MANAGEMENT IN WYOMING 1 (2011), http://deq.wyoming.gov/media/attachments/Solid%20%26%20Hazardous%20Waste/Solid%20Waste/Guidance%20%26%20Standards/SHWD_Solid-Waste_Guidelines-24-Naturally-Occurring-Radioactive-Material-NORM-Management-In-Wyoming_2011-08_BqBJnMq.pdf [https://perma.cc/D9PA-PQDV].

impacted natural soils at the surface or 8 [pCi/g Ra-226] and/or decommissioned equipment from crude oil or gas operations exceeding 50 [µR/hr] emanation rate at any accessible point."[237] The Wyoming guidance, where NORM wastes have not been removed, distinguishes between NORM contaminated soils, scale, sludge and tank bottoms and equipment.[238] Management of NORM and TENORM is permitted in solid waste landfills if waste is less than or equal to 30 pCi/g of Ra-226 up to 20 cubic yards.[239] If levels are more than 50 pCi/g then the waste must be transferred to a low-level radioactive waste facility outside of Wyoming.[240] NORM equipment contaminated with less than 50 µR/hr can be recycled, and up to 20 tons may be disposed of in a State permitted solid waste disposal facility.[241]

10. Louisiana

Natural gas was first discovered in Louisiana in 1870.[242] The first commercially operated oil wells were drilled at the turn of the 20th century.[243] Louisiana passed its first legislative measure governing oil in 1906.[244] The State has a long history of oil and gas production, with the State reaching an estimated 64,710 wells as of 2015.[245]

The Louisiana Department of Environmental Quality (LDEQ) issued regulations to deal with wastes from oil and gas operations. LDEQ accepts NORM wastes in Subtitle D landfills if the waste is less than or equal to 5 pCi/g above background levels.[246] Under State regulations, NORM and aspects of TENORM are covered including those from oil and gas.[247] The exemption limit for disposal is set at 5 pCi/g or less of Ra-226 or Ra-228 or

---

237. *Id.* at 2.
238. *Id.*
239. *Id.* at 5.
240. *Id.*
241. *Id.* at 5–6.
242. *Historical Louisiana Fracking Information*, BALLOTPEDIA, https://ballotpedia.org/Historical_Louisiana_fracking_information [https://perma.cc/PN4J-X8JH] (last visited Feb. 5, 2018).
243. *Id. See generally* Alex Ritchie, *Fracking in Louisiana: The Missing Process/Land Use Distinction in State Preemption and Opportunities for Local Participation*, 76 LA. L. REV. 809, 811 (2016) (discussing issues of land use and drilling process between state and local governments of Louisiana).
244. *Historical Louisiana Fracking Information*, *supra* note 242.
245. Kelso, *supra* note 124.
246. *Exploration and Production (E&P) Waste*, LA. DEP'T OF ENVTL. QUALITY http://www1.deq.louisiana.gov/portal/DIVISIONS/WastePermits/ExplorationandProductionEPWaste.aspx [https://perma.cc/54A7-PGMD] (last visited Feb. 5, 2018).
247. LA. ADMIN. CODE tit. 33 pt. XV §§ 1402–14 (2015).

150 pCi/g of any other NORM radionuclide.[248] NORM-contaminated equipment is exempt if the maximum radiation exposure level does not exceed 50 µR/hr.[249] "Produced waters from crude oil and natural gas production are exempt from the requirements of these regulations," but subject to regulations pertaining to water quality.[250]

In Louisiana, NORM disposal can occur by any of the following:

> (1) by transfer of the wastes to a land disposal facility licensed by [LDEQ], or the U.S. Nuclear Regulatory Commission, an agreement state, or a licensing state;
> (2) by alternate methods authorized in writing by LDEQ upon application or the department's initiative . . .;
> (3) for nonhazardous oilfield waste containing NORM at concentrations not exceeding 30 [pCi/g] of radium-226 or radium-228 by transfer to a nonhazardous oilfield waste commercial facility regulated by the Department of Natural Resources [DNR] for treatment if the following are met:
> a. dilution in the end product after treatment does not exceed 5 [pCi/g] above background of radium-226 or radium-228;
> b. the nonhazardous oilfield waste commercial facility has a program for screening incoming shipments to ensure that the 30 [pCi/g] limit of radium-226 or radium-228 is not exceeded; and
> c. the DNR approves; or
> (4) for nonhazardous oilfield waste containing concentrations of NORM more than the limits in LAC 33: XV.1404.A.1, but not exceeding 200 [pCi/g] of radium-226 or radium-228 and daughter products, by treatment at nonhazardous oilfield waste commercial facilities specifically licensed by the department for such purposes.[251]

These regulations cover the protection of workers by referencing the protections found under the general radiation provisions.[252]

11. New Mexico

---

248. *Id.* at § 1404.
249. *Id.*
250. *Id.*
251. *Id.* at § 1412(B)(1)–(4).
252. *Id.* at § 1411.

New Mexico has an estimated 60,943 wells[253] that are mostly located in the San Juan Basin.[254] New Mexico also overlies part of the Permian Basin, a significant oil-producing formation that produces approximately 2.4 million barrels per day.[255] New Mexico, like Texas, has a detailed regulatory framework for NORM disposal (although the definition of TENORM reads akin to the way many states define NORM).[256] New Mexico regulates NORM-bearing materials in the oil and gas industry and their disposal in solid waste facilities, and as such New Mexico requires testing prior to leaving the well.[257] New Mexico stipulates specific disposal options for oil and gas NORM in: (1) non-retrieved flowlines and pipelines; (2) disposal of NORM at commercial or centralized surface waste management facilities; (3) disposal of NORM in plugged and abandoned wells; and (4) deep well injection of NORM from the oil and gas industry.[258]

The disposal limits, which are specific to oil and gas, are subject to licensure requirements set forth in the general radiation provisions.[259] This makes New Mexico the only state in the U.S. to apply their general radiation standards and licensing specifically to NORM generated during oil and gas extraction, transfer, transport, storage, or disposal.[260] Regulations on NORM generated in the oil and gas industry also apply to sludges and scale deposits in tubulars and equipment and to cleaning operations.[261] Under § 20.3.14.1403, New Mexico sets exemption limits of "30 [pCi/g] or less of radium 226, above background, or 150 [pCi/g] or less of any other NORM radionuclide, above background, in soil, in 15 cm layers, averaged over 100 square meters"; the exemption limit for

---

253. Kelso, *supra* note 124. *See generally* Alex Ritchie, *On Local Fracking Bans: Policy and Preemption in New Mexico*, 54 NAT. RESOURCES J. 255 (2014) (discussing fracking in New Mexico); Jonas Armstrong, *What the Frack Can We Do: Suggestions for Local Regulation of Hydraulic Fracturing in New Mexico*, 53 NAT. RESOURCES J. 357 (2013) (estimating the number of wells in New Mexico).

254. *Fracking in New Mexico*, BALLOTPEDIA, https://ballotpedia.org/Fracking_in_New_Mexico [https://perma.cc/A3GM-CMRZ] (last visited Feb. 5, 2018).

255. *Permian Basin Oil Production and Resource Assessments Continue to Increase*, U.S. ENERGY INFO. ADMIN. (Apr. 26, 2017), https://www.eia.gov/todayinenergy/detail.php?id=30952 [https://perma.cc/R7FM-6PUE].

256. *See generally* Ritchie, *supra* note 253, at 277 (comparing New Mexico and Texas disposal frameworks).

257. N.M. CODE R. § 20.3.14.1407 (LexisNexis 2001).

258. N.M. CODE R. § 19.15.35.10–13 (LexisNexis 2007).

259. N.M CODE R. § 20.3.14.6 (LexisNexis 2001).

260. *Id.*

261. *Id*. at § 20.3.14.2.

contaminated equipment is 50 µR/hr; and sludges and scales are exempt if Ra-226 does not exceed 30 pCi/g.[262]

New Mexico sets worker protection guidelines that include limits to exposure for workers with licenses, such as "[a]ny worker engaged in an activity subject to a Specific License and who is likely to receive in one year an accumulative dose in excess of 500 mrem (5 mSv) shall be monitored."[263] Protections for the general New Mexico population are set to not exceed 100 mrem (1 mSv) in a year or 2 mrem (.020 mSv) for an unrestricted area in any one hour.[264]

12. Kentucky

Kentucky has an estimated 32,483 wells,[265] mostly in the Devonian Shale.[266] Kentucky was the first state in the U.S. to become an agreement state.[267] In Kentucky, TENORM is classified as low-level radioactive waste[268] and is defined as "[n]aturally occurring radioactive material with a radionuclide concentration that has been increased by [or because] of human activities."[269] Per the Central Midwest Interstate Low-Level Radioactive Waste Commission Compact, Kentucky laws govern the disposal of TENORM such that 2,000 pCi/g of TENORM waste may be

---

262. *Id*. at § 20.3.14.1403(A), (C).

263. *Id*. at. § 20.3.14.1405(E).

264. *Id*. at § 20.3.14.1406.

265. Kelso, *supra* note 124.

266. *See, e.g.*, *Hydraulic Fracturing in Kentucky*, KY. DIV. OF OIL AND GAS, http://oilandgas.ky.gov/Documents/Fracing%20Brochure.pdf [https://perma.cc/M9KH-MMC9] (last visited Feb. 5, 2018) (noting Devonian Shale is an "'unconventional' reservoir which must be fractured to enhance natural gas production").*See generally* Diana M. Papoulias & Anthony L. Velasco, *Histopathological Analysis of Fish from Acorn Fork Creek, Kentucky, Exposed to Hydraulic Fracturing Fluid Releases*, 12 SE. NATURALIST 92 (2013) (discussing the impact of fracking in Kentucky); Andrew S. Holcomb, DEP'T. OF EARTH AND ENVTL. SCIENCES, Presentation at the 2016 Eastern Section AAPG: Monitoring Induced Microseismicity in the Rome Trough, Eastern Kentucky U.S.A. (Sept. 26, 2016) (discussing the changes in seismic activity in the Rome Trough); Thomas N. Sparks, Kentucky Geologic Survey, Presentation at the 2016 Eastern Section AAPG: Class II Injection Wells in Kentucky-An Update of the Map Service of Wastewater, Brine Disposal and Enhanced Recovery Wells in Kentucky (Sept. 26, 2016) (outlining fracking in Kentucky); Thomas N. Sparks, Class II Injection Wells in Kentucky – An Update of the Map Service of Wastewater, Brine-Disposal, and Enhanced Recovery Wells in Kentucky (Sept. 26, 2016) (outlining fracking in Kentucky).

267. *State Agreement Program*, U.S. NUCLEAR REG. COMM'N, https://www.nrc.gov/about-nrc/state-tribal/agreement-states.html [https://perma.cc/Z4HL-FZL2] (last updated Aug. 31, 2017).

268. KY. REV. STAT. ANN. § 211.893 (West 2016).

269. KY. REV. STAT. ANN. § 211.862(13) (West 2017).

disposed of at a LLRW facility.[270] For all industries, radioactive waste including NORM can be disposed of:

(1) By transfer to an authorized recipient as provided in 902 KAR 100:040, Section 12, or 902 KAR 100:022;
(2) By decay in storage;
(3) By release in an effluent within the limits in 902 KAR 100:019, Section 10;
(4) [By] treatment or disposal by incineration;
(5) [By] decay in storage; or
(6) [By] disposal at a land disposal facility licensed under 902 KAR 100:022.[271]

TENORM is also defined under general radiation provisions in a manner different than conventional definitions in other states such that TENORM is "N.O.R.M., which has been separated to various degrees from the original ore or other material, refining or implementing it."[272]

The lack of a consistent regulatory framework has led some to question whether TENORM waste is adequately addressed in Kentucky. Purported illegal dumping of fracking waste from West Virginia and Ohio has led to calls for legislative action to end loopholes that allow improper disposal to occur in Kentucky.[273]

13. Utah

Since commercial production began in 1948 in the Uinta Basin, Utah has produced more than 1.2 billion barrels of oil and more than 6 trillion cubic feet of natural gas.[274] As of 2015, Utah has an estimated 27,352 wells.[275] NORM, not TENORM, is subject to general licensing requirements, which set disposal limits of 15 pCi/g for Ra-226, with concentrations in excess of this limit requiring a radioactive material

---

270. CENT. MIDWEST INTERSTATE & LOW-LEVEL RADIOACTIVE WASTE COMM'N, *supra* note 230, at 28.

271. 902 KY. ADMIN. REGS. 100:021.

272. 902 KY. ADMIN. REGS. 100:010 (Feb. 2015).

273. Dan Heyman, *TENORM in KY Landfills: Loopholes, Questionable Business Practices*, PUBLIC NEWS SERV. (Aug. 3, 2016), http://www.publicnewsservice.org/2016-08-03/environment/tenorm-in-ky-landfillsloopholes-questionable-businesspractices/a53347-1 [https://perma.cc/9FZN-LPXB].

274. *Historical Utah Fracking Information*, BALLOTPEDIA, https://ballotpedia.org/Historical_Utah_fracking_information [https://perma.cc/9VLB-QL8H] (last visited Feb. 5, 2018).

275. Kelso, *supra* note 124.

license.[276] While Utah does not specifically address TENORM or NORM generated in oil and gas operations, Utah does permit a LLRW facility to take in up to 10,000 pCi/g of Ra-226.[277]

14. New York

New York has an estimated 24,435 oil and gas wells.[278] Under general radiation provisions, NORM is defined. TENORM containing waste is a regulated waste stream; however, TENORM is referred to as processed and concentrated NORM rather than TENORM.[279]

There is currently a state-wide fracking moratorium in New York,[280] but environmentalists worry fracking waste is being imported from nearby Pennsylvania for disposal in New York.[281] Thus, some are concerned that New York may not be properly addressing TENORM waste in the oil and gas industry from conventional drilling occurring in the state and wastes from unconventional drilling from outside the state.[282]

15. Montana

Montana has an estimated 19,928 wells.[283] With the recent resurgence in the development of oil and gas resources in Montana[284] and neighboring

---

276. UTAH ADMIN. CODE R. 313-19-13 (2017).

277. ENERGY*SOLUTIONS* CLIVE, UTAH, BULK WASTE DISPOSAL AND TREATMENT FACILITIES WASTE ACCEPTANCE CRITERIA 42 (2015).

278. Kelso, *supra* note 124.

279. N.Y. COMP. CODES R. & REGS. tit. 6, § 380-1.2 (2017).

280. Press Release, N.Y. State Senate, 20 Senators Urge Closure of Fracking Waste Loophole (Aug. 24, 2016), https://www.nysenate.gov/newsroom/press-releases/liz-krueger/20-senators-urge-closure-fracking-waste-loophole [https://perma.cc/6FPN-KDHK].

281. *See* RIVERKEEPER, FRACKING WASTE IN NEW YORK, https://www.riverkeeper.org/wp-content/uploads/2016/02/FW-toolkit-ALL-handouts.pdf [https://perma.cc/3TXV-N3BC] (last visited Feb. 7, 2018) (detailing the transportation and storage of ranking wastewater in New York).

282. *See generally* HEATHER COOLEY & CHRISTINA DONNELLY, PAC. INST., HYDRAULIC FRACTURING AND WATER RESOURCES: SEPARATING THE FRACK FROM THE FICTION 19 (2012), http://pacinst.org/wp-content/uploads/2014/04/fracking-water-sources.pdf [https://perma.cc/5YQK-T78S] (discussing the environmental impacts of hydraulic fracturing); REBECCA HAMMER ET AL., NAT. RESOURCES DEF. COUNCIL, IN FRACKING'S WAKE: NEW RULES ARE NEEDED TO PROTECT OUR HEALTH AND ENVIRONMENT FROM CONTAMINATED WASTEWATER 10–11 (2012), https://www.nrdc.org/sites/default/files/Fracking-Wastewater-FullReport.pdf [https://perma.cc/RM58-YFST] **(**evaluating the need to address contaminated wastewater from fracking).

283. Kelso, *supra* note 124.

284. WASTE MGMT. & REMEDIATION DIV., MONT. DEP'T OF ENVTL. QUALITY, DEVELOPMENT OF TENORM RULES FOR THE STATE OF MONTANA 10 (2016), https://deq.mt.gov/Portals/112/Land/SolidWaste/Documents/docs/TENORMReportFinal.pdf [https://perma.cc/VPU4-WCTB]; *see also* Memorandum from Ed Thamke, Chief, Waste and

states, the State developed new guidance. In 2013, Montana opened its first special oilfield waste facility. This facility can accommodate many of the wastes from neighboring North Dakota, which was only able to dispose of oil and gas wastes containing 5 pCi/g until 2015.[285] Permit appeals or public hearings for such facilities are non-existent unlike in other states such as Colorado.[286] Montana's Solid Waste Program (SWP) has developed landfill-management procedures to handle these drilling wastes.[287] Under Montana rules, oil and gas wastes are commonly referred to as exploration and production (E&P) wastes.[288]

Oil and gas wastes in Montana are considered exempt "nonhazardous E&P" wastes.[289] These are regulated in Montana as a "'[s]pecial waste,' mean[ing] a solid waste that has unique handling, transportation, or disposal requirements to ensure protection of the public health, safety, and welfare and the environment."[290] Minimum requirements for management of E&P wastes at licensed solid waste management facilities in Montana include:

(1) Analyzing unprocessed E&P waste for Radium-226, Radium-228, and Lead-210; and
(2) Analyzing processed E&P wastes for Radium-226, Radium-228, Lead-210, Thorium-232, and Polonium-210.[291]

Another significant requirement under the Montana guidance is creation and maintenance of a leachate collection and removal system with a synthetic liner that sets a limit of less than or equal to 50 pCi/g for Ra-226 and Ra-228.[292] For all other leachate collection and removal system designs, the limit is less than or equal to 15 pCi/g for Ra-226 and Ra-228.[293]

Underground Tank Management Bureau, Mont. Dep't of Envtl. Quality, on NORM/TENORM Policy Change (Dec. 7, 2015), https://deq.mt.gov/Portals/112/Land/SolidWaste/Documents/docs/TENORMChangeMEMO120715.pdf [https://perma.cc/3E52-6G5H] ("In order to be commensurate with regional States, DEQ is proposing in policy to increase disposal limits for NORM and TENORM from 30 picocuries per gram (pCi/gm) to less than or equal to 50 pCi/gm for Ra-226 and Ra-228 for landfills with leachate collection and removal system with a synthetic liner. DEQ believes this increase enables Montana to stay conservative yet consistent with nearby states for landfill acceptance criteria while remaining protective of public health and the environment.").

285. WESTERN ORG. OF RES. COUNCILS, *supra* note 213, at 18.

286. *Id*. at 20.

287. SOLID WASTE PROGRAM, MONT. DEP'T OF ENVTL. QUALITY, REQUIREMENTS FOR THE MANAGEMENT OF SPECIAL WASTES ASSOCIATED WITH THE DEVELOPMENT OF OIL AND GAS RESOURCES 1 (2015).

288. *Id.*

289. *Id.* at 1, 3.

290. MONT. CODE ANN. § 75-10-802(8) (2005).

291. SOLID WASTE PROGRAM, *supra* note 287, at tbl. 1.

292. *Id.* at tbl. 2.

293. *Id.*

Finally, Montana established guidance for radioactive contamination of scale, sludge, and contaminated equipment.[294]

16. Michigan

Michigan has an estimated 19,821 wells.[295] Michigan is not an agreement state.[296] The State has, however, issued cleanup and disposal guidelines for sites contaminated with Ra-226.[297] Unlike many other states, Michigan does not regulate disposal of Ra-228 because of the belief that it results in negligible amounts in waste streams.[298] Instead, Michigan focuses on Ra-226. Michigan recommends the development of a regulatory framework for the handling of wastes containing Pb-210 as it can be further concentrated in natural gas streams.[299]

Michigan regulates disposal of up to 50 pCi/g of Ra-226 in Type I and Type II landfills (with no differentiation between landfills) and 5 pCi/g for soil cleanup criteria.[300] Amounts more than 50 pCi/g should be transferred to a licensed radioactive waste facility.[301] Michigan also requires disposal of TENORM at least 10 feet below the bottom of the landfill cap and leachate and groundwater monitoring for Ra-226.[302] Michigan oil and gas

---

294. *Id.*

295. Kelso, *supra* note 124. *See generally* Christopher Borick et al., *Public Opinion on Fracking: Perspectives from Michigan and Pennsylvania*, ISSUES ENERGY & ENVTL. POL'Y, May 2013, at 1 (discussing the public opinion about fracking in Michigan).

296. *State Agreement Program*, U.S. NUCLEAR REG. COMM'N, https://www.nrc.gov/info-finder/region-state/michigan.html [https://perma.cc/DXH9-AMMA] (last updated Oct. 5, 2016).

297. OFFICE OF WASTE MGMT. AND RADIOLOGICAL PROT., MICH. DEP'T OF ENVTL. QUALITY, CLEANUP AND DISPOSAL GUIDELINES FOR SITES CONTAMINATED WITH RADIUM-226 2 (2013), http://www.michigan.gov/documents/deq/EQC_1602_Cleanup_and_Disposal_Guidelines_for_Sites_Contaminated_with_Radium-226_526418_7.pdf [https://perma.cc/PJ7G-BN2F] [hereinafter CLEANUP AND DISPOSAL GUIDELINES].

298. KAREN P. SMITH ET AL., U.S. DEP'T OF ENERGY, AN ASSESSMENT OF THE DISPOSAL OF PETROLEUM INDUSTRY NORM IN NONHAZARDOUS LANDFILLS 5 (1999).

299. MICH. DEP'T OF ENVTL. QUALITY, MICHIGAN TENORM DISPOSAL ADVISORY PANEL WHITE PAPER 5 (2014–2015), https://www.michigan.gov/documents/deq/deq-RMG-TENORM_Disposal_Advisory_Panel_White_Paper_-_FINAL_481404_7.pdf [https://perma.cc/UR32-QXSD] [hereinafter MICHIGAN TENORM DISPOSAL ADVISORY PANEL WHITE PAPER].

300. CLEANUP AND DISPOSAL GUIDELINES, *supra* note 297, at 1.

301. *Id.*

302. MICHIGAN TENORM DISPOSAL ADVISORY PANEL WHITE PAPER, *supra* note 299, at 4; KAREN P SMITH ET AL., U.S. DEP'T OF ENERGY, AN ASSESSMENT OF THE DISPOSAL OF PETROLEUM INDUSTRY NORM IN NONHAZARDOUS LANDFILLS 3 (1999), http://www.evs.anl.gov/downloads/Smith-et-al-1999-Landfill-Disposal-of-NORM.pdf [https://perma.cc/8P9C-LWL7].

regulations govern plugged and abandoned wells.[303] More than 50 pCi/g of waste must be transferred to a licensed radioactive waste facility.[304]

Michigan law defines naturally occurring material as "radioactive material found radioactive in the normal isotopic distribution of elements rather than rendered radioactive by artificial means."[305] The Radioactive Materials Unit is responsible for NORM "found in oil, gas, brine, chemical, and water treatment industries."[306] The Supervisor of Wells and the Supervisor of Mineral Wells issued Order 3-6-92 that defines NORM and ways of disposing of it.[307]

17. Arkansas

Arkansas has 18,645 wells.[308] The State's radiation control regulation provides NORM regulations; however, it is not specific to oil and gas.[309] Facilities and equipment contaminated with NORM less than or equal to 50 μR/hr, including background, are exempt from licensure requirements.[310] The exemption limit is "5 [pCi/g] of radium-226 and/or radium-228 . . . or 150 [pCi/g] of any other NORM radionuclide."[311] Disposal methods at permitted facilities and licensed facilities adhere to general radiation provision guidelines as well as federal guidelines.[312]

18. North Dakota

North Dakota has 17,931 wells.[313] North Dakota sits atop the Bakken Formation of the Williston Basin along with six other fields; experts estimate that the Bakken Formation contains at least 7 billion barrels of

---

303. MICH. ADMIN. CODE r. 324.901 (1996).

304. MICHIGAN TENORM DISPOSAL ADVISORY PANEL WHITE PAPER, *supra* note 299 at 7.

305. MICH. ADMIN. CODE r. 325.5012.

306. *Radioactive Material*, MICH. DEP'T OF ENVTL. QUALITY, http://www.michigan.gov/deq/0,4561,7-135-3312_4120_4244---,00.html [https://perma.cc/BRU2-JDXE] (last visited Feb. 7, 2018); *see also* MICH. COMP. LAWS ANN. § 333.13515 (1978) (defining the duties of Michigan's Radioactive Materials Unit).

307. DEP'T OF NAT. RES., ORDER NO. 3-6-92, OPINION AND ORDER OF THE SUPERVISOR OF WELLS AND SUPERVISOR OF MINERAL WELLS (Nov. 3, 1992).

308. Kelso, *supra* note 124. *See generally* Svetlana Ikonnikova et al., *Profitability of Shale Gas Drilling: A Case Study of the Fayetteville Shale Play*, BUREAU ECON. GEOLOGY, U. OF TEX. AUSTIN (2015) (discussing unconventional oil and gas in Arkansas).

309. 7.14.1 ARK. CODE R. § 6004 (2016).

310. *Id.* § 6010(b).

311. *Id.* § 6005(a).

312. *Id.* § 7001.

313. Kelso, *supra* note 124.

recoverable oil reserves.[314] The recent boom in shale gas extraction in North Dakota has prompted State officials to take several actions.[315] The North Dakota Department of Health directed the North Dakota Argonne National Laboratory to conduct a study on TENORM to evaluate TENORM disposal in landfills and possible exposures to workers and the public.[316] Following this study, licensure requirements for TENORM were enacted under the general radiation provisions, covering both worker protections and general public protections.[317] Exemption limits for conventional disposal of TENORM, which includes both scale and sludge, is 5 pCi/g of Ra-226 and Ra-228 in any combination thereof.[318] North Dakota also prohibits purposeful dilution to render TENORM exempt from the regulations.[319]

Changes were also made to solid-waste regulations, as it pertains to landfill disposal of TENORM waste. TENORM waste less than or equal to 50 pCi/g of Ra-226 and Ra-228 may be disposed of in a landfill, and a contaminated-equipment limit is set at 100 µR/hr.[320] Additionally, the "[d]isposal of TENORM waste subject to regulation under [general radiation provisions] is prohibited in all municipal solid waste landfills and inert landfills."[321] The State requires monitoring of leachate and

---

314. *Fracking in North Dakota*, BALLOTPEDIA, https://ballotpedia.org/Fracking_in_North_Dakota [https://ballotpedia.org/Fracking_in_North_Dakota] (last visited Feb. 7, 2018); *see also* Nancy E. Lauer et al., Brine Spills Associated with Unconventional Oil Development in North Dakota, 50 ENVTL. SCI. & TECH. 5389, 5389–97 (2016) (discussing production in the Bakken Shale); R.M. Horner et al., *Water Use and Management in the Bakken Shale Oil Play in North Dakota*, 50 ENVTL. SCI. & TECH. 3275, 3275 (2016) (outlining population growth rates associated with the potential of the Bakken Shale reserves); Bret A. Weber et al., *Rural North Dakota's Oil Boom and its Impact on Social Services*, 59 SOCIAL WORK 62-72 (2014) (discussing the history of oil production in the Bakken Shale); DEAN A. BANGSUND & NANCY M. HODUR, PETROLEUM INDUSTRY'S ECONOMIC CONTRIBUTION TO NORTH DAKOTA IN 2011, NDSU AGRIBUSINESS AND APPLIED ECONOMICS REPORT 29 (2013) (discussing employment and economic benefits to the Bakken Shale region from oil production); Joshua P. Fershee, *The Oil and Gas Evolution: Learning from the Hydraulic Fracturing Experiences in North Dakota and West Virginia*, 19 TEX. WESLEYAN L. REV. 23, 24 (2012) (examining oil production in the Bakken Shale); Heather Ash, *EPA Launches Hydraulic Fracturing Study to Investigate Health and Environmental Concerns While North Dakota Resists Regulation: Should Citizens Be Concerned*, 87 N.D. L. REV. 717, 730–31 (2011) (analyzing

315. *See generally* R.M. Horner et al., *supra* note 314, at 3275 (discussing the management impacts from the rapid development of Bakken Shale play).

316. N.D. DEP'T OF HEALTH, *supra* note 67.

317. N.D. ADMIN. CODE 33-10-23-05, 33-10-23-06 (2016).

318. *Id.* 33-10-23-04.

319. *Id.* 33-10-23-09.

320. N.D. ADMIN. CODE 33-20-11-01 (2016).

321. *Id.* 33-20-11-02.

groundwater analysis for background concentrations of radionuclide parameters before receipt of any TENORM waste.[322] The regulations state:

> If radionuclides are detected in the leachate at a concentration greater than the concentrations listed below, then the groundwater monitoring network must begin analysis for radionuclide parameters.
>
> Radon: 4,000 picocuries per liter (pCi/L).
>
> Combined radium-226 and radium-228: 5 pCi/L.
>
> Alpha particle activity (including radium-226, excluding radon and uranium): 15 pCi/L.
>
> Uranium: 30 micrograms per liter (ug/L) [sic].[323]

Worker training and safety at landfills approved for the disposal of TENORM waste is implemented pursuant to regulations so that protection of workers complies with radiation protection standards.[324]

According to the North Dakota Department of Health's website, North Dakota has taken steps to specify that oil and gas disposal wells have leak-proof, covered containers for disposal of radioactive filter socks.[325] In addition, the transportation of TENORM waste now requires a radioactive transportation licensure.[326] While North Dakota's measures are a step in the right direction, there are inconsistencies between the 5 pCi/g under general radiation provisions and the 50 pCi/g under waste management rules.

19. Tennessee

Tennessee has 15,814 wells,[327] with drilling occurring in the Chattanooga Shale Formation.[328] Tennessee has guidelines for TENORM disposal, which regulates the disposal of TENORM in accordance with the

---

322. *TENORM Waste: A Guide to Regulatory & Disposal Concerns*, HAZARDOUS WASTE EXPERTS (Sept. 26, 2014), http://www.hazardouswasteexperts.com/tenorm/ [https://perma.cc/K9RS-R64U].

323. N.D. ADMIN. CODE 33-20-11-04 (2016).

324. *Id*. 33-20-11-06.

325. *TENORM Waste: A Guide to Regulatory & Disposal Concerns*, *supra* note 322.

326. N.D. ADMIN. CODE 33-10-23-28 (2016).

327. Kelso, *supra* note 124.

328. *Historical Tennessee Fracking Information*, BALLOTPEDIA, https://ballotpedia.org/Historical_Tennessee_fracking_information [https://perma.cc/XHM9-K26Q] (last visited Feb. 7, 2018).

following options for a licensee: "(a) [b]y transfer to an authorized recipient as provided in other chapters of these regulations; [or] (b) [b]y decay in storage;" or for the person receiving waste: "(a) [t]reatment prior to disposal; (b) [t]reatment or disposal by incineration; (c) [d]ecay in storage; or (d) [d]isposal at a licensed land disposal facility."[329]

20. Virginia

Virginia has 11,850 wells,[330] and drilling occurs in the southwest part of the state in the organic-rich Marcellus Shale. State regulations generally address TENORM and NORM in its state radiation control regulations, but are not specific to oil and gas.[331] As with most states that provide general radiation standards, the exemption limit for general disposal requirements is set at 5 pCi/g for Ra-226 and Ra-228, and 200 μrem/hr at 1 cm for TENORM contaminated equipment.[332]

21. Mississippi

Mississippi has 7,897 wells.[333] Since 1923, Mississippi has used natural gas to generate electricity, prompting the formation of the Mississippi Oil and Gas Board in 1932 as the regulatory body for the State's oil and gas industry.[334] Mississippi has adopted rules governing the disposal of NORM in the oil and gas industry.[335] NORM, not TENORM, is defined as "any nuclide which is radioactive in its natural physical state . . . but does not include byproduct, source or special nuclear material nor does it include radioactive materials continuously contained within the closed system of exploration and production of oil and gas, including but not limited to

---

329. TENN. COMP. R. & REGS. 0400-20-05-.120 (2014); *see also* TENN. COMP. R. & REGS. 0400-54-01-.03 (2014) (indicating NORM and TENORM from oil and gas should be disposed according to the Tennessee radiation regulations).

330. Kelso, *supra* note 124.

331. *See* 12 VA. ADMIN. CODE § 5-481-10 (2017) (discussing NORM and TENORM but not oil and gas).

332. 12 VA. ADMIN. CODE § 5-481-3510 (2008).

333. Kelso, *supra* note 124.

334. *Historical Mississippi Fracking Information*, BALLOTPEDIA, https://ballotpedia.org/Historical_Mississippi_fracking_information [https://perma.cc/X9XV-S9RG] (last visited Feb. 7, 2018).

335. 26-002 MISS. CODE R. § 1.68 (LexisNexis 2017).

produced saltwater."[336] As outlined in the rule, the following are acceptable disposal methods:

> (1) Placement between cement plugs; or
> (2) Encapsulation in pipe then placed between cement plugs; or
> (3) Mixed with gel or mud (slurried) and placed between cement plugs; or
> (4) Slurried then placed into a formation; or
> (5) Surface landspreading; or
> (6) Subsurface landspreading; or
> (7) Disposal offsite at a licensed, and low level radioactive waste or NORM disposal facility . . . .[337]

A land-spreading limit is set at 5 pCi/g, and the groundwater table must be located at least 5 feet from the bottom of the disposal area.[338]All disposal options are outlined and must meet approved criteria set forth in the rule. Rule 69 of the regulations of the Mississippi Oil and Gas Board focuses on handling NORM in the field, which includes worker and public protections.[339]

Additionally, Mississippi regulates NORM through its general radiation provisions on licensing of NORM.[340] The exemption limit concentration must be

> less than 5 picocuries per gram of radium - 226 or radium - 228 above background; or, concentrations less than 30 picocuries per gram . . . of technologically enhanced radium-226 or radium-228, averaged over any 100 square meters, provided the radon emanation rate does not exceed 20 picocuries . . . per square meter per second, or 150 picocuries per gram . . . of any other NORM radionuclide . . . .[341]

Contaminated equipment should "not exceed 25 microroentgens per hour above background radiation at any accessible point."[342]

22. Nebraska

---

336. *Id.* § 1.68(I)(7).
337. *Id.* § 1.68(IV)(1-8).
338. *Id.* § 1.68(V)(4).
339. *Id.* § 1.69(1)(a).
340. *See* MISS. CODE ANN. § 45-14-3 (West 1972) (stating the general objective of the regulation which his to prevent or reduce harmful radiation waste).
341. 15-01 MISS. CODE R. §1100.04(1)(a).
342. *Id.* §1100.04(1)(b).

Nebraska sits upon the Niobrara Shale Formation and has a total of 3,140 wells.[343] Nebraska is not historically considered an area with a large natural gas play or an area with great reserves of oil. However, because of advancements in hydraulic fracturing, the number of operating wells is increasing.[344] A weak regulatory framework on disposal of TENORM wastes generated during operations may pose future problems and lead to radiological risks from exposure to wastes to workers and the public.[345] TENORM is defined, and the exemption limit to radiation standards is set at 5 pCi/g for Ra-226 and its progeny, but may prove insufficient.[346]

23. Ohio

Ohio has 1,916 wells.[347] Ohio sits atop the Utica Shale, which sits below the Marcellus Shale—a large reserve for natural gas that caused the production of shale gas to rise exponentially between 1990 and 2004.[348] Ohio is one of the recent states to take measures to deal with fracking waste generated, including TENORM.[349] Both NORM and TENORM are classically defined.[350] The radiation control regulation on TENORM mentions worker and public protection in general without reference to oil and gas as part of a license requirement and release criteria.[351] TENORM waste from oil and gas is under the jurisdiction of the Oil and Gas Division.[352] The disposal limit at 5 pCi/g requires monitoring of leachate and groundwater for Ra-226, Ra-228, and others.[353] Regulations define

---

343. Kelso, *supra* note 124.

344. *Fracking in Nebraska*, BALLOTPEDIA, https://ballotpedia.org/Fracking_in_Nebraska [https://perma.cc/GD5D-5NXT] (last visited Feb. 7, 2018).

345. *See* 180 NEB. ADMIN. CODE § 3-004.03(4) (2016) (discussing TENORM in a limited way compared to other states).

346. *Id.*

347. Kelso, *supra* note 124.

348. *Fracking in Ohio*, BALLOTPEDIA, https://ballotpedia.org/Fracking_in_Ohio [https://perma.cc/6SS3-YU55] (last visited Feb. 7, 2018). *See generally* Andrew R. Thomas et al., *An Analysis of the Economic Potential for Shale Formations in Ohio*, URBAN PUBLICATIONS (2012).

349. OHIO DEP'T OF HEALTH, NORM/TENORM INFORMATION SHEET 3, https://www.odh.ohio.gov/-/media/ODH/ASSETS/Files/rp/Raducation/Module-3---NORM-TENORM-Information-Sheet.pdf [https://perma.cc/CE53-GW8N] (last visited Feb. 7, 2018). *See generally* MELISSA BELCHER & MARVIN RESNIKOFF, RADIOACTIVE WASTE MANAGEMENT ASSOCIATES, HYDRAULIC FRACTURING RADIOLOGICAL CONCERNS FOR OHIO (2013) (providing background on the impact and cost of inadequate radioactive waste disposal in Ohio).

350. OHIO ADMIN. CODE 3701:1-38-01 (2014); OHIO ADMIN. CODE 3701:1-43-07 (2014).

351. *Id.*

352. OHIO REV. CODE ANN. § 1509.02 (West 2013).

353. OHIO REV. CODE ANN. § 3734.02 (West 2005).

scale and contaminated equipment in terms of TENORM.[354] Per the Ohio Department of Health, TENORM must be tested before leaving the well for Ra-226 and Ra-228.[355]Other oil and gas waste, such as brine containing NORM, is disposed of in underground injection wells and pursuant to a different set of standards and exempt from laws governing TENORM.[356] This last part could prove to be problematic because of the distinction Ohio makes between NORM and TENORM, possibly opening the State to loopholes in the law.

Per radiation protection standards for TENORM, the exemption limit is set as 5 pCi/g of Ra-226 or Ra-228 and 50 µR/hr for contaminated equipment.[357] Thus, the solid waste landfill disposal limit of 5 pCi/g exists for Ra-226 and Ra-228, as authorized by the State.[358] Scale is regulated as TENORM. Ohio requires that solid waste landfills and transfer facilities must first get TENORM analytical results for Ra-226 and Ra-228 before accepting waste from oil and gas drilling.[359]

24. Washington

Washington has 721 wells.[360] While Washington does not have provisions regarding TENORM or NORM in their general radiation or oil and gas provisions, the State does permit a LLRW facility to accept up to 10,000 pCi/g of NORM.[361] Like other states with little natural gas drilling activity, a minimum TENORM licensing requirement should be established with appropriate limits.

25. South Dakota

354. OHIO ADMIN. CODE 3701: 1-43-07 (2014).
355. OHIO DEP'T OF HEALTH, *supra* note 349.
356. *Id.*
357. Jim Colelli, *Ohio Department of Health Issue Paper* (Sept. 10, 2012), http://www.odh.ohio.gov/-/media/ODH/ASSETS/Files/rp/radiation-protection/2013/2014/BRP-Position-on-Ra-Background-2012.pdf?la=en [https://perma.cc/R8LS-VCGD]; OHIO ADMIN. CODE 3701:1-43-07 (2014).
358. *Id.*
359. OHIO ENVTL. PROTECTION AGENCY, IMPACT OF HB 59 ON SOLID WASTE LANDFILLS AND TRANSFER FACILITIES 2 (2013), http://epa.ohio.gov/Portals/34/document/guidance/FINAL%20-%20HB59%20Guidance%20Document%20100113.pdf [https://perma.cc/L9E4-FBNX].
360. Kelso, *supra* note 124.
361. *TENORM Waste Issues Waste Acceptance Criteria*, U.S. ECOLOGY (Feb. 2016) http://ncrponline.org/wp-content/themes/ncrp/PDFs/HPS_NCRP_Workshop_2-2016_PRESENTATIONS.pdf [https://perma.cc/K25J-RDH9].

South Dakota has 587 wells.[362] The first producing oil well was drilled in 1953, and drilling mostly takes part in the northeast part of the state in the Bakken Shale Formation in the Williston Basin.[363] Given the small number of wells in the state, new legislative measures may not be necessary for TENORM-bearing wastes in the oil and gas industry. South Dakota is not, however, an agreement state nor does it generally license TENORM.[364] Interestingly, South Dakota has provisions prohibiting the disposal of more than 5 pCi/g Ra-226 and Ra-228 in solid waste disposal facilities in the state.[365]

26. Oregon

Oregon has 522 wells.[366] NORM, not TENORM, is licensed under general radiation provisions, which set the limit for conventional disposal options at 5 pCi/g for radium and 150 pCi/g of any NORM nuclide.[367] Contaminated equipment is addressed in the context of NORM; however, scale, sludge, produced water, and drill cuttings are not.[368] These regulations are not specific to oil and gas, and they do not address TENORM.

27. Arizona

Arizona has 369 wells.[369] Despite the low number of wells and activity, the Oil and Gas Commission established a set of guidelines pertaining to these operations.[370] Neither Arizona's regulations nor general radiation provisions, however, include TENORM or NORM waste.[371] Thus, Arizona may inadequately dispose of TENORM waste.

28. Idaho

---

362. Kelso, *supra* note 124.
363. *Historical South Dakota Fracking Information*, BALLOTPEDIA, https://ballotpedia.org/Historical_South_Dakota_fracking_information [https://perma.cc/5KUV-25X3] (last visited Feb. 7, 2018).
364. *State Agreement Program*, U.S. NUCLEAR REG. COMMISSION, https://www.nrc.gov/info-finder/region-state/sdakota.html [https://perma.cc/M5D9-CZPQ] (last updated June 30, 2015).
365. S.D. CODIFIED LAWS § 34A-6-114 (2017).
366. Kelso, *supra* note 124.
367. OR. ADMIN. R. 333-117-0040 (1991).
368. *Id.*
369. Kelso, *supra* note 124.
370. Steven Rauzi, *Is Hydraulic Fracturing a Threat in Arizona?*, ARIZ. GEOLOGY MAG. (Apr. 5, 2012), http://azgeology.azgs.az.gov/article/oil-and-gas/2012/04/hydraulic-fracturing-threat-arizona [https://perma.cc/J5YM-S6EN].
371. *Id.*

Idaho has 152 wells.[372] TENORM and NORM are covered under general radiation provisions.[373] Outside of the general radiation provisions, TENORM is covered under the solid waste management regulations, which prohibit the disposal of TENORM at solid waste disposal facilities; thus, disposal can only occur at RCRA Subtitle C landfills.[374] These TENORM regulations set exposure limits for members of the public, but lack specificity as to measuring exposure.[375] While Idaho may not be a major producer of oil and gas, other states may not dispose of TENORM waste in State municipal solid waste landfills, but only at RCRA Subtitle C landfills.[376]A RCRA Subtitle C facility run by U.S. Ecology does, in fact, accept up to 1,500 pCi/g of TENORM wastes containing radium, and receives oil and gas wastes from as far as Pennsylvania.[377]

B. States with Active Wells that Have No NORM & TENORM Regulations

The next grouping of states does not address NORM or TENORM in any of their state laws or regulations.

Alabama has 8,017 wells.[378] Alabama's first oil wells were drilled in 1865 and commercially drilled since the 1900s.[379] In the late 1970s, reserves were discovered offshore in the Gulf of Mexico, and a few years later coalbed natural gas reserves were drilled in the Black Warrior River.[380] The rise in production prompted the Alabama Oil and Gas Board to establish the State's first set of comprehensive drilling operations laws. These laws do not, however, account for today's technological advances in shale gas extraction. Controversy has loomed over Alabama's shale gas extraction industry.[381] For example, protests ended attempts to lease over 40,000 acres in the Talladega National Forest.[382] Alabama's laws and

---

372. Kelso, *supra* note 124.
373. IDAHO ADMIN. CODE r. 58.01.10 (2002).
374. *Id*. at 58.01.10.020.03(a).
375. WESTERN ORG. OF RES. COUNCILS, *supra* note 213, at 16.
376. *Id.* at 12.
377. *Id*.
378. Kelso, *supra* note 124.
379. DOUGLAS R. HALL & DAVID E. BOLIN, THE PETROLEUM INDUSTRY IN ALABAMA, 1999–2007 1–11 (Eric V. St. Clair & Gary W. Crawford eds., 2009).
380. *Id.*
381. Juliet Eilpernin, *Forest Lands in the East Attract Oil and Gas Bidders, but Some Question Rush*, WASH. POST (June 8, 2012), https://www.washingtonpost.com/national/health-science/forest-lands-in-the-east-attract-oil-and-gas-bidders-but-some-question-rush/2012/06/08/gJQA8lOvNV_story.html?utm_term=.fb5c9c5ac361 [https://perma.cc/G7W5-YFS6].
382. *Id.*

regulations do not adequately define waste from TENORM and NORM, despite the State's long history of oil and gas production.[383]

Indiana has 7,672 wells,[384] Missouri has 6,590 wells,[385] and Alaska has 5,643 wells.[386] These states are not agreement states and do not have regulations addressing TENORM or NORM disposal.[387]

Florida has 123 wells.[388] Florida is an agreement state, but Florida does not define TENORM or NORM in any of its laws or codes. The limited number of wells and reserves in the state do not necessitate massive changes in current regulatory standards. The State's general radiation provisions should at least define TENORM and NORM, which would provide necessary worker and public health protections.

Maryland is also an agreement state[389] and has only 57 wells.[390] Until October 1, 2017, the State did not permit hydraulic fracturing.[391]

C. NORM & TENORM Regulations in States Without Oil & Gas Drilling

The following states have no drilling operations.[392] South Carolina covers licensing of NORM and TENORM establishing conventional requirements for worker and public protections.[393] South Carolina's NORM regulations provide an exemption limit for contaminated equipment of 50 μR/hr.[394] The exemption limits for NORM radionuclides include: (1) 30 pCi/g or less of technologically enhanced Ra-226 or Ra-228 if the radon emanation rate is less than 20 pCi per square meter per second; (2) 5 pCi/g or less of technologically enhanced Ra-226 or Ra-228 if the radon emanation rate is greater than or equal to 20 pCi per square meter per

---

383. *Id.*
384. Kelso, *supra* note 124.
385. *Id.*
386. *Id.*
387. *Id.*
388. *Id.*
389. OFFICE OF NUCLEAR MATERIAL SAFETY & SAFEGUARDS, U.S. NUCLEAR REGULATORY COMM'N, *supra* note 134.
390. *Id.*
391. H.B. 1325, 2017 Leg., 740 Sess. (Md. 2017); *see also* Meleah D. Boyle et al., *Hazard Ranking Methodology for Assessing Health Impacts of Unconventional Natural Gas Development and Production: The Maryland Case Study*, 11 PLOS ONE 1, 2 (2016) (describing the methodology used to assess the public health risk as Maryland considered gas development and production in the Marcellus Shale).
392. Kelso, *supra* note 124.
393. S.C. CODE ANN. REGS. 61-63, § 9.1 (2010) (referring to TENORM as TENR).
394. *Id.* § 9.3.1.7.

second; and (3) 150 pCi/g or less of any other NORM radionuclide.[395] These protections would be sufficient at a minimum.

New Jersey does not have any active drilling wells.[396] Still, the State may be improperly addressing disposal of TENORM waste imported into the state. For instance, New Jersey disposes of drill cuttings and drilling waste from neighboring states such as Pennsylvania.[397] New Jersey's general radiation provisions define NORM and TENORM and can serve as a standard for disposal amounts.[398] Currently, New Jersey limits TENORM licensing to 5 pCi/g for Ra-226 or Ra-228.[399] Additionally, New Jersey provides guidelines for minimum remediation standards for TENORM-contaminated sites. These guidelines may benefit New Jersey, considering the State accepts imported TENORM waste.[400] Another Mid-Atlantic state, Delaware, is not an agreement state[401] and does not define TENORM.[402]

Georgia's NORM licensing requirements define NORM and TENORM.[403] Like South Carolina, Georgia distinguishes between NORM and TENORM in setting conventional disposal limits. For example, Georgia exempts:

> (1) 30 picocuries . . . per gram or less of technologically-enhanced radium-226 or radium-228 . . . [if] the radon emanation rate is less than 20 pCi . . . per square meter per second or;
> (2) 5 pCi . . . per gram or less of technologically-enhanced radium-226 or radium-228 . . . [if] the radon emanation rate is equal to or greater than 20 pCi . . . per square meter per second; or
> (3) 150 pCi . . . or less per gram of any other NORM radionuclide . . . .[404]

Georgia's regulations also address contaminated equipment and scale, limiting contaminated equipment to 50 µR/hr.[405]

---

395. *Id.* § 9.3.1.
396. Kelso, *supra* note 124.
397. Matt Kelso, *Where Does the Waste From PA's Marcellus Wells Go?*, FRACTRACKER ALLIANCE (Mar. 14, 2012), https://www.fractracker.org/2012/03/where-does-the-waste-from-pas-marcellus-wells-go/ [https://perma.cc/CQ9V-VBAR].
398. N.J. Admin. Code § 7:28-1.4 (2017).
399. *Id.* § 7:28-4.3.
400. *Id.*
401. OFFICE OF NUCLEAR MATERIAL SAFETY & SAFEGUARDS, U.S. NUCLEAR REGULATORY COMM'N, *supra* note 134.
402. 16 DEL. ADMIN. CODE § 4465-A-2.0 (2016).
403. GA. COMP. R. & REGS. 391-3-17.08(2)(a)–(c), (7)(a), (10)(a) (2002).
404. *Id.* 391-3-17.08(4)(a)(1)–(3).
405. *Id.* 391-3-17.08 (4)(f).

New England lacks abundant, if any, oil and gas reserves. Thus, these states do not typically address NORM or TENORM waste. Vermont is not an agreement state.[406] Vermont law prohibits hydraulic fracturing for oil and gas. Additionally, Vermont prohibits handling wastewater from hydraulic fracturing operations.[407] Massachusetts defines NORM, but not TENORM.[408] Connecticut, which is not an agreement state,[409] prohibits the transfer and disposal of hydraulic fracturing waste.[410] New Hampshire's general radiation standards define NORM.[411] Rhode Island regulations and laws do not address TENORM or NORM. Lastly, Maine regulations define TENORM and provide for classic disposal options limited to 5 pCi/g of any combination of Ra-226 or Ra-228.[412] Maine's general radiation provisions protect workers and the public; however, these protections are not specific to oil and gas.[413] Maine's TENORM licensing provisions address contaminated equipment, but fail to address sludge, scale, produced water, or drill cuttings.[414]

Additionally, Minnesota, Iowa, Wisconsin, Hawaii, and the District of Columbia have no oil and gas activity and no specific NORM or TENORM guidelines.[415] Similarly, North Carolina is not producing natural gas or oil[416] and lacks TENORM or NORM regulations. In 2014, however, the North Carolina State Legislature passed the Energy Modernization Act.[417] This Act lifted the ban on oil and gas exploration, allowing possible extraction of the State's shale gas.[418] Like North Carolina, Nevada has engaged in limited or no shale oil and gas extraction.[419] However, the

---

406. OFFICE OF NUCLEAR MATERIAL SAFETY & SAFEGUARDS, U.S. NUCLEAR REGULATORY COMM'N, supra note 134.

407. VT. STAT. ANN. tit. 29, § 571 (2012).

408. *See* 105 MASS. CODE REGS. 120.005 (2016) (defining terms applicable to Massachusetts's Radiation Control Program).

409. OFFICE OF NUCLEAR MATERIAL SAFETY & SAFEGUARDS, U.S. NUCLEAR REGULATORY COMM'N, *supra* note 134.

410. CONN. GEN. STAT. § 22a-472(a)–(g) (2017).

411. N.H. Rev. Stat. § 125-F:3 (2013).

412. 10-144-220 ME. CODE R. § 4-5 (2009).

413. *Id.* § 5.

414. *Id.* § 13.

415 *See generally Regulations for the Control of Naturally Occurring Radioactive Materials – An Update*, NORM REPORT, Spring 2001 (listing NORM regulations for different states).

416. Kelso, *supra* note 124.

417. S.B. 786, Gen. Assemb., Reg. Sess. (N.C. 2013)

418. *See generally* Bryan M. Weynand, *Placing the Seal on a Fractured Debate: How North Carolina Clarified Its Law of Hydraulic Fracturing and Can Strike the Right Balance with Preemption of Local Regulation*, 93 N.C. L. REV. 596 (2015) (summarizing North Carolina's Energy Modernization Act and its effects on oil and gas regulations within the state).

419. Kelso, *supra* note 124.

Eastern Great Basin's potential for oil and gas extraction may influence Nevada's participation in the industry.[420]

VI. BY THE NUMBERS

Table 3 describes how many states allow different disposal options for TENORM and NORM in the oil and gas industry.

Disposal Options for TENORM/NORM	# of States	States
Disposal at a Licensed Land Disposal Facility	18	Arkansas, Georgia, Idaho, Kentucky, Louisiana, Maine, Mississippi, Montana, New Mexico, New York, North Dakota, Ohio, Oregon, South Carolina, Tennessee, Texas, Virginia, West Virginia
Disposal at a Low-Level Radioactive Waste Facility	4	Mississippi, Washington, Utah, Illinois
Disposal at a Permitted Solid Waste Disposal Facility	12	California, Colorado, Idaho, Louisiana, Maine, Michigan, Montana, New Mexico, North Dakota, Ohio, South Dakota, Wyoming
Disposal in Plugged and Abandoned Wells	3	New Mexico, Texas, Mississippi

420. *Fracking in Nevada*, BALLOTPEDIA, https://ballotpedia.org/Fracking_in_Nevada [https://perma.cc/9EBT-CLUY] (last visited Feb. 7, 2018) (discussing the Eastern Basin's gas deposits under Nevada and Utah).

Burial	3	Texas, Colorado, North Dakota
Land-spreading	4	New Mexico, Texas, Kansas, Mississippi
Incineration	3	Kentucky, South Carolina, Tennessee
Deep Well Injection	7	Colorado, Maine, Michigan, Mississippi, New Mexico, Ohio, Texas
Disposal in Non-Retrieved Flow-lines and Pipelines	1	New Mexico
Reuse	1	Colorado
Treatment Prior to Disposal	5	Colorado, Kentucky, Louisiana, South Carolina, Tennessee

Table 4 describes the permissible disposal limits and disposal options for TENORM and NORM by state.

States with Limits	Limits (pCi/g)	Type of Permit/Disposal
Texas	30 pCi/g for Ra-226 and Ra-228	State rule for general disposal, land-spreading, disposal by burial
Kansas	10 pCi/g for Ra-226 and Ra-228	Land-spreading
California	1,800 TENORM waste	Disposal permit at permitted facility
Colorado	2,000 TENORM waste	Disposal permit at permitted facility
Illinois	2,000 TENORM waste	Disposal permit at LLRW facility
Wyoming	30 pCi/g up to 20 cubic yards; 30–50 pCi/g up to 10 cubic yards; 50 piC/g	Disposal at a permitted solid waste disposal facility
Louisiana	30 pCi/g Ra-226 and Ra-228 for nonhazardous oilfield waste at commercial facilities; 200 pCi/g Ra-226 and/or Ra-228 at a	Disposal at a licensed land disposal facility, disposal at a permitted solid waste disposal facility, treatment prior to disposal

	licensed treatment facility	
New Mexico	30 pCi/g for Ra-226 and 150 pCi/g for any NORM radionuclide	Disposal at a permitted solid waste disposal facility, disposal in plugged and abandoned wells, land-spreading, deep well injection, disposal in non-retrieved flow-lines and pipelines
Kentucky	2,000 pCi/g TENORM waste	Disposal permit at LLRW facility
Montana	50 pCi/g for Leachate Collection and Removal System and Synthetic Liner and 15 pCi/g for natural clay liner for combined Ra-226 and Ra-228	Disposal at a permitted solid waste disposal facility
Michigan	50 pCi/g for Ra-226	Disposal at a permitted solid waste disposal facility
North Dakota	50 pCi/g for Ra-226 and/or Ra-228	Disposal at a permitted solid waste disposal facility, burial
Mississippi	5 pCi/g for Ra-226 and Ra-228	Land-spreading
Ohio	5 pCi/g for Ra-226 and Ra-228	Disposal at a licensed land disposal facility, disposal at a permitted solid waste disposal facility, deep well injection, treatment prior to disposal
Washington	10,000 pCi/g TENORM waste	Disposal at a LLRW facility

South Dakota	N/A	Disposal at a permitted solid waste disposal facility

CONCLUSION

Texas, Pennsylvania, Oklahoma, Louisiana, and Wyoming are the top five greatest producers of oil and gas. Many states may be inadequately addressing drilling wastes generated by oil and gas extraction. Complicating the issue, regulating agencies may confront jurisdictional overlap while regulating NORM and TENORM waste. Clear guidance, laws, and regulations are necessary to facilitate safety and health in states where inadequacies could harm humans, animals, and the environment.

The problem presents two questions. First, how do oil and gas producing states dispose of the resulting waste? Second, how do states receiving waste from others ensure adequate protection? States with long histories of oil and gas exploration, such as Texas and New Mexico, have established disposal options that may minimize the amount of waste exported. But, with new technologies[421] such as high-volume hydraulic fracturing[422] and horizontal drilling,[423] some states are experiencing a boom in natural gas production,[424] creating more waste. Although Connecticut has no active wells, the State has forbidden the importation of any oil and gas waste. Additionally, Pennsylvania transports most of its drilling waste to New York, Ohio, New Jersey, Maryland, and West Virginia; these states may not have adequate protections for workers and the public, especially

---

421. *See generally* 43 C.F.R. § 3160 (2015) (noting ways to prevent waste given the new technology).

422. *See* Agarwal, *supra* note 4, at 362 (evaluating the effectiveness of hydraulic fracturing); Method and Materials for Hydraulic Fracturing of Wells, U.S. Patent No. 6,949,491, at 1 (filed Sept. 24, 2002) (outlining the process for hydraulic fracturing).

423. *See* Gary D. Libecap, *The Political Allocation of Mineral Rights: a Re-Evaluation of Teapot Dome*, 44. J. ECON. HIST. 381, 381–91 (1984) (discussing the developments in horizontal drilling); Method and Apparatus for Horizontal Drilling, U.S. Patent No. 5,148,875 (filed Sept.24, 1991) (showing the set up for hydraulic fracturing); Method of Horizontal Drilling, U.S. Patent No. 5,165,491 (filed April 29, 1991) (outlining the method for hydraulic fracturing).

424. Anne K. Smith, *Cash In on the Natural Gas Shale Boom*, KIPLINGER TODAY (Oct. 31, 2011), http://www.kiplinger.com/article/business/T019-C000-S002-cash-in-on-the-natural-gas-shale-boom.html [https://perma.cc/LT7N-W2N2].

considering the alarming amount of waste disposed of in "unspecified locations."[425]

States such as Pennsylvania and North Dakota are experiencing a boom in their economies from oil and gas extraction in the Marcellus and Bakken shales.[426] States with bans on fracking, or those with limited oil and gas resources, also receive indirect economic benefit by importing these wastes.[427] New York, for instance, does not permit shale gas extraction. Since New York accepts waste imports from Pennsylvania, it should consider expanding regulatory protections, and perhaps limit the amount of waste it imports.[428]

States should outline specific criteria and detailed requirements of disposal options as well as tracking manifests. New Mexico has adopted comprehensive waste disposal laws and could serve as a model for other states. Specifically, New Mexico requires a survey of TENORM waste prior to leaving the well site.[429] Other states, like Michigan and Pennsylvania, designate TENORM waste to areas in landfills equipped to handle radioactivity.[430] These processes, coupled with continuous monitoring, may present one requirement for states to consider.

Texas and Louisiana have adopted regulatory limits that are perhaps less protective than the 5 pCi/g limit. These limits may, however, be more representative of the waste generated during oil and gas operations. Depending on the disposal option, tiered TENORM disposal limits may be prudent. States should reevaluate these options to determine the best disposal methods based on geology, topography, risks, etc.

Some states, such as Wyoming and Pennsylvania, have chosen not to regulate low-risk TENORM waste. Yet, studies cited in this article suggest that low-dose exposure to TENORM may be harmful to human health and the environment due to the radiological risks. States should set exposure limits based on engineering, medical, and public-health perspectives. Thus, future studies should look at these regulatory limits as they relate to human and environmental health.

Texas takes measures to prohibit disposal options that may unnecessarily cause overexposure to radioactive waste. Other states, which allow for widespread unconventional oil and gas operations, should also

---

425. Kelso, *supra* note 124.

426. *See* Timothy J. Considine et al., ECON. OPPORTUNITIES OF SHALE ENERGY DEV. 1,3, 6 (May 2011) (expressing the economic boom regarding oil and gas extraction).

427. *Id.*

428. Kelso, *supra* note 124.

429. N.M. CODE R. § 20.3.14.1407 (LexisNexis 2001).

430. CLEANUP AND DISPOSAL GUIDELINES, *supra* note 297.

develop policies, guidance, or regulations addressing ambiguities in their general radiation provisions.

Many states rely on their general radiation provisions to cover NORM and TENORM wastes, but this could prove problematic given the dichotomy of oil and gas operations. States with abundant production totals must enact measures addressing drilling wastes. Oklahoma has no general radiation provisions, and therefore does not regulate TENORM waste generated during oil and gas production.

This lack of protection for these workers and nearby residents potentially exposes them to unnecessary radiation risks. States should incorporate worker and public safety measures that consider unconventional oil and gas operations. States should adopt guidance for site safety and health plans for oil and gas operations. As one example, workers should wear badges that monitor exposures during upstream and downstream activities. Additionally, states should implement engineering and institutional controls including cleaning contaminated equipment in well-ventilated areas or limiting worker exposures through shift changes.

Unconventional oil and gas production is controversial. Proponents argue that natural gas is relatively cleaner and more economically sustainable for producers, manufacturers, businesses, and individuals. Opponents cite to pollution and radiological concerns that can negatively impact human and environmental health. On a broader level, some state policies hinder the options available for TENORM disposal. Thus, prudence requires safe and effective ways for reducing TENORM waste.