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**STATE OF NEW MEXICO
BEFORE THE WATER QUALITY CONTROL COMMISSION**

IN THE MATTER OF PROPOSED NEW
RULE 20.6.8 NMAC –
*Ground and Surface Water Protection –
Supplemental Requirements For Water Reuse*

No. WQCC 23 - 84 (R)

NEW MEXICO ENVIRONMENT DEPARTMENT,
WATER PROTECTION DIVISION,

Petitioner.

REBUTTAL TECHNICAL TESTIMONY AND EXHIBITS

OF

AVNER VENGOSH

ON BEHALF OF

NEW ENERGY ECONOMY

May 6, 2024

1 **Q. Please state your name and business address.**

2 A. Avner Vengosh, PhD

3 Distinguished Professor and Nicholas Chair of Environmental Quality

4 Chair, Division of Earth and Climate Sciences

5 LSRC A-317, Nicholas School of the Environment

6 Duke University

7 Durham, NC 27708

8 **Q. On whose behalf are you testifying in this proceeding?**

9 A. I am testifying on behalf of New Energy Economy (“NEE”).

10 **Q. Please summarize your educational background and your professional experience**
11 **related to water regulation.**

12 A. I am a Distinguished Professor of Environmental Quality at Duke University. I am also
13 the Chair of the Division of Earth and Climate Sciences at the Nicholas School of the
14 Environment in Duke University (see my curriculum vitae, Exhibit AV-1). My team and I
15 have studied the energy-water nexus, conducting pioneer research on the impact of hydraulic
16 fracturing and coal ash disposal on the quantity and quality of water resources in the U.S. and
17 China. I have also investigated the sources and mechanisms of water contamination in
18 numerous countries across the globe, focusing the mechanisms that control the occurrence of
19 geogenic contaminants such as salinity, arsenic, fluoride, boron, hexavalent chromium,
20 radium, and uranium. My group has developed geochemical and isotope tracers that are used
21 to delineate sources and mechanisms of water contamination. See,

22 <https://www.youtube.com/watch?v=WfpVAM82KuQ>. I am a Fellow of the Geological

23 Society of America (GSA) and of the International Association of Geochemistry (IAGC). In

1 2019, 2020 and 2021, I was recognized as one of the Web of Science Highly Cited
2 Researchers. I have served as an Editor of GeoHealth and on the editorial board of
3 Environmental Science and Technology. I have published 180 scientific papers in leading
4 international journals, including 34 scientific papers directly addressing the potential impact
5 of oil produced water on the environment (see Exhibit AV -2). My recent cross-disciplinary
6 book "*Water Quality Impacts of the Energy-Water Nexus*" (Cambridge University Press,
7 2022) provides an integrated assessment of the different scientific and policy tools around the
8 energy-water nexus. This book provides an extensive evaluation of the chemistry of oil and
9 gas wastewater and numerous examples of how the release of oil produced waters to the
10 environment causes major ecological and human health risks.

11 **Q. Have you appeared before the Water Quality Control Commission before or**
12 **submitted testimony?**

13 A. I have not appeared before the Water Quality Control Commission ("Commission" or
14 "WQCC"). I have provided testimony to the U.S. Congress, the U.S. Office of Management
15 and Budget (OMB), and the U.S. EPA.

16 **Q. Have you reviewed Proposed Rule 20.6.8 NMAC?**

17 A. Yes, I have.

18 **Q. Do you understand that NMED has submitted the Reuse Rule for adoption by the**
19 **WQCC, and what is your response?**

20 A. From my extensive and long-term (over 20 years) research on the chemistry of oil
21 produced water across the U.S., including oil wastewater from the Permian Basin, I can
22 clearly testify that the use of oil produced water without adequate treatment would cause
23 numerous environmental effects and would contaminate soil and water by organic, inorganic

1 (metals), and radioactive materials for decades to come. In addition, it would pose human
2 health risks on individual associated with the oil wastewater and the impacted areas. As part
3 of my research, I have investigated the long-term impact of using low-saline oil produced
4 water for irrigation in California, and in spite of the low salinity the data show accumulation
5 of some of the oil produced water chemicals in the irrigated soils. Without any specification
6 of the treatment methods and the capacity to remove all organic, inorganic, and radioactive
7 materials from oil produced water, the new Reuse Rule is inadequate and cannot be used for
8 recycling and reusing oil produced water in New Mexico.

9 **Q. While NMED supports no direct discharge of produced water, what are your**
10 **concerns with “reuse”?**

11 A. Numerous studies, including my own research (see Exhibit AV-2), have shown that oil
12 produced water contains elevated levels of toxic organic chemicals, salts, metals, and
13 contaminants such as ammonium and radium nuclides, which are extremely toxic for the
14 ecological systems and human health. In addition to the direct contamination of water
15 resources impacted by spills or even discharge of treated oil produced water, high
16 concentrations of radioactive elements such as radium nuclides in oil produced water poses
17 risks for the accumulation of the radioactive elements on the soil (in the case of using oil
18 wastewater for irrigation) or streams (in cases of disposal of treated oil wastewater). It has
19 been shown that disposal of treated oil wastewater to streams and rivers has caused high
20 levels of radioactivity in the sediments in the outfall sites. Given the high level of salinity and
21 elevated levels of other contaminants in oil produced water specifically from the Permian
22 Basin, reuse of untreated or inadequately treated oil wastewater in New Mexico is clearly
23 impossible and would cause a major environmental damage.

1 Yet, the Reuse Rule includes ambiguous language of the “appropriate treatment” for possible
2 reuse of oil produced water, without specification of the treatment methods and without
3 including comprehensive management plans for addressing the waste that would be
4 generated from the treatment systems. In a best-case scenario, where desalination technology
5 such as reverse osmosis and other treatment methods would be utilized to remediate oil
6 produced water, it would generate highly saline and radioactive wastewater that would
7 require special management and removal. The absence of clear indications of the treatment
8 technologies and the water quality standards as conditions for the ability to reuse,
9 implementation of the new Reuse Rule could generate numerous environmental issues, which
10 would require high economic cost for future remediation.

11 In a Master Thesis titled “*Recycling Produced Water in the Permian Basin*” by Carly
12 Osborne, my former student at Duke University (available at
13 [https://dukespace.lib.duke.edu/server/api/core/bitstreams/29f577ad-582c-43b1-bd83-
14 d8735203c049/content](https://dukespace.lib.duke.edu/server/api/core/bitstreams/29f577ad-582c-43b1-bd83-d8735203c049/content)), the utility of the treatment capacity of oil produced water was
15 investigated. The study investigated oil produced water from the Permian Basin prior to and
16 after treatment in Chiltepin Recycling Plant in Pecos, Texas. The results showed that the high
17 salinity of oil produced water (total dissolved salts of 44,000 mg/L) has also extremely high
18 levels of ammonium (178 mg/L). In 2013, the U.S. EPA has recommended water quality
19 criteria for chronic aquatic life expressed as Total Ammonia Nitrogen is 1.9. The ammonium
20 content in the Permian Basin oil produced water is therefore about 90-fold higher than the
21 maximum level allowed to be disposed to surface water. Furthermore, one of the most
22 important findings of the Master Thesis was that the treated oil produced water in Chiltepin
23 Recycling Plant had the exact same concentrations as the untreated water for all inorganic

1 constituents including ammonium. Therefore, although classified as “treated oil produced
2 water”, utilization of the treated water from Chiltepin Recycling Plant would have induced
3 major environmental and ecological damages and would have been a danger to human health.
4 It is important to emphasize that water quality standards for different utilization needs (e.g.,
5 irrigation) contain only constituents that are common in natural waters, such as salinity,
6 sodium, and boron contents. Yet oil produced water is composed of a very wide range of
7 organic and inorganic chemicals that may not be included in the utilization standards, and
8 therefore, applying these regulations may miss the impact of other constituents not included
9 in the standards. For example, the level of the radioactive element radium is unlikely to be
10 included in any of the utilization standards, yet the high concentration of radium in oil
11 produced water poses additional risks for long-term accumulation in the impacted soil.

12 **Q. Mr. Michael Hightower, Director of the New Mexico Produced Water Consortium**
13 **claims that his direct testimony presents “a summary of the Consortium’s research and**
14 **risk and toxicology findings” in combination with “credible scientific data” and the**
15 **“best available scientific data”¹ and after a “review and interpretation of the current**
16 **produced water discharge regulations for applications in New Mexico concludes [that]**
17 **the treatment and reuse of produced water is encouraged for all uses.”² Do you agree**
18 **with his testimony?**

19 A. No I do not and here is why: 1) As I said above, without the specification of treatment and
20 standards, this Rule is not scientifically-based; and 2) Without credible scientific data to base
21 a regulation on, any reuse application will cause undue risk: any “demonstration project” or

¹ Notice of Intent to Present Oral Testimony by Mr. Michael Hightower, Director of the New Mexico Produced Water Consortium at 9. (Apr. 15, 2024).

² Id., at 12.

1 “industrial project” authorized by this Reuse Rule will adversely impact human health and
2 the environment and will cause impairment to waterways and be destructive to property.

3 **Q. What is your response to the following direct testimony of Mr. Robert S. Balch:**

4 A. Balch testimony argues that “*So long as produced water satisfies water quality standards,*
5 *it should not be treated differently from other water.*”³ This statement is fundamentally
6 incorrect. As mentioned above, produced water contain a large range of toxic organic and
7 inorganic chemicals including NORMs. Many of these chemical components are not
8 included in water quality standards that were designed to address primarily marginal waters
9 from domestic wastewater. Therefore, following the water quality standards alone would not
10 address the risks induce from oil produce water and would cause severe environmental and
11 human health impacts upon implementation of this new ruling. Furthermore, Balch’s
12 statement “*Moreover, water that is a by-product of reuse of treated produced water should*
13 *no longer fall within the definition of produced water*”⁴ is misleading and factually incorrect;
14 while produced water is treated for reducing turbidity, for example, the treated water would
15 still contain high levels of other contaminants and the “treated water” is still potentially could
16 pose major environmental and human health risks. This was demonstrated in the case of
17 Chiltepin Recycling Plant in in Pecos, Texas that I mentioned earlier. While oil produced
18 water in this facility was treated to remove suspended solids and organics, it was not treating
19 the inorganic chemicals in the produced water, and, consequently, the treated water had the
20 same levels of salts and inorganic contaminants as the non-treated produced water.

21 Therefore, treated oil produced water should be evaluated for all the chemicals at all the

³ New Mexico Oil and Gas Association’s Notice of Intent to Present Technical Testimony, Direct Testimony of Robert S. Balch, at 18, Bates Stamp 000045.

⁴ Id.

1 different stages of treatment. It is essential that any new Water Quality Control Commission
2 Rule require the evaluation of the quality of the treated produce water and include treated
3 water at different stages of treatment under the definition of oil produced water.

4 **Q. Please comment on Balch’s recommendation.**

5 A. Balch concludes: “*As previously stated, technically, any water can be cleaned to existing*
6 *or future water quality standards, and no restrictions would be necessary if cost were not an*
7 *object. All waste or marginal water is ultimately recyclable[.]*”⁵ However, public health and
8 the environment could be put at extreme risk if one measures “treated” produced water against
9 domestic water quality standards. Water quality standards test for fecal matter and pH and bio-
10 chemical oxygen, etc., but this evaluation frequently does not call for measurements of
11 radionuclides or volatile organic compounds that occur in produced water. Mr. Balch’s
12 unscientific and grossly irresponsible statement that “*[s]o long as produced water satisfies*
13 *water quality standards, it should not be treated differently from other water*” should be
14 rejected outright by this Commission because it is not only misleading, it is dangerous and
15 risky. Further, Mr. Balch is going out of his way to confuse different classes of “water.”
16 “Produced water” is waste generated from hydraulic fracturing process and involves
17 hypersaline brines that cannot be characterized or confused with natural water or even domestic
18 wastewater. Produced water is laden with a wide range of highly toxic organic compounds,
19 dissolved mineral salts, and naturally-occurring radioactive material (NORM). This
20 Commission must be guided by science not by self-serving statements that have no basis in
21 scientific scholarship.

⁵ Id.

1 Additionally, cost is an object. Large-scale treatment of produced water may eventually be
2 possible but there is no evidence at this time that it has been proven or that it can be
3 accomplished in an economically feasible manner.

4
5 **Conclusion**

6 Without a scientifically-based definition of the treatment methods and the associated
7 management plans designed for oil produced water from the Permian Basin, the Reuse Rule
8 poses major risks to the environment and human health.

9
10 **Q. Does this conclude your rebuttal testimony?**

11 A. Yes, it does.

EXHIBIT LIST FOR THE REBUTTAL TESTIMONY OF AVNER VENGOSH

Exhibit AV-1 – Avner Vengosh’s curriculum vitae.

Exhibit AV-2 – List of Publications of Avner Vengosh on oil produced waters.

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NEW MEXICO ENVIRONMENT DEPARTMENT,
WATER PROTECTION DIVISION,

Petitioner.

SELF AFFIRMATION

Avner Vengosh, expert witness for New Energy Economy, upon penalty of perjury under the laws of the State of New Mexico, affirm and state: I have read the foregoing Rebuttal Technical Testimony & Exhibits of Avner Vengosh and it is true and correct based on my own personal knowledge and belief.

Dated this 6th day of May 2024.

A handwritten signature in black ink, appearing to read 'Avner Vengosh', with a stylized, cursive script.

AVNER VENGOSH, PhD

Avner Vengosh
Duke University Distinguished Professor of Environmental Quality
Chair of the Division of Earth and Climate Sciences

Nicholas School of the Environment & Earth Sciences
Division of Earth & Climate Sciences
Duke University
Box 90227, Durham, NC 27708-0235

Telephone: (919) 681-8050
Fax: (919) 684-5833
E-mail: vengosh@duke.edu

Publications and Grants Summary

• Publications: total – 178 scientific papers in peer-reviewed journals; Google Scholar Stats: h-index=76 (i10-index=179); 23,126 total citations. Web of Science: h-index=66; 15,634 total citations. Grants: PI or co-PI on federal and foundation awards totaling ~\$13 millions since 2005. **Named to the 2019, 2020, and 2021 Highly Cited Researchers List** - production of multiple highly-cited papers that rank in the top 1% by citations for field and year in Web of Science.

EDUCATION

Australian National University AUSTRALIAN NATIONAL UNIVERSITY, RESEARCH SCHOOL OF EARTH SCIENCE

Canberra, Australia

• Ph.D., 1990, Environmental Geochemistry (Thesis title: *Boron isotope geochemistry in the sedimentary environment*).

Advisor: Professor Allan Chivas and Professor Malcolm McCulloch.

HEBREW UNIVERSITY OF JERUSALEM, Jerusalem, Israel

• M.Sc., 1986, Isotope Geology (Thesis title: *Stable isotopes in coexisting phases of phosphatic, carbonate and siliceous rocks of the Mishash Formation, Israel*).

Advisor: Professor Yehushua Kolodny.

HEBREW UNIVERSITY OF JERUSALEM, Jerusalem, Israel

• B.Sc., 1984.

ACADEMIC APPOINTMENTS

Duke University, Durham, NC, USA

Nicholas School of the Environment,

2023- *Chair of the Division of Earth and Climate Sciences*

Duke University, Durham, NC, USA

Nicholas School of the Environment,

2023- *Nicholas Chair of Environmental Quality*

Duke University, Durham, NC, USA

Nicholas School of the Environment,

2021- *Distinguished Professor of Environmental Quality*

Duke University, Durham, NC, USA

Nicholas School of the Environment, Division of Earth and Earth Sciences,

2010- *Professor (tenured)*

Duke University, Durham, NC, USA
Nicholas School of the Environment, Division of Earth and Earth Sciences,
2005 -2010 *Associate Professor (tenured)*

Duke University, Durham, NC, USA
Pratt School of Engineering, Department of Civil and Environmental Engineering,
2009 - *Secondary Appointment*

Stanford University, Stanford, California, USA,
Department of Geological and Environmental Sciences,
August 2003 – March 2004, *Visiting Professor (sabbatical leave)*

Ben Gurion University, Beer Sheva, Israel,
Department of Geological and Environmental Sciences,
1999 -2005 (since 2002 tenured position), *Associate Professor*

University of California, Santa Cruz, California, USA,
Institute of Earth and Marine Sciences,
1996-1997, *Visiting Scientist (sabbatical leave)*

Hydrological Service, Jerusalem, Israel
Research Department,
1991-1999, *Senior Lecturer*

HONORS

2011 - International Association of Geochemistry (IAGC) Fellow.

2013 - Best Science Paper Award, *Environmental Science & Technology*.

2014 - Second Runner-Up Best Environmental Policy Paper, *Environmental Science & Technology*.

2015 - Geological Society of America (GSA) Fellow.

2016 - Environmental Science and Technology Excellence in Review Award.

2016 - Paper on groundwater geochemistry in areas of the Fayetteville Shale is one of the 5 most highly cited papers published in *Applied Geochemistry*.

2017 - Selected by American Chemical Society as the highest prolific authors for the journal *Environmental Science and Technology Letters*.

2017 - Selected by American Chemical Society as the author of the most cited paper in *Environmental Science and Technology*.

2018 – Paper “*The geochemistry of naturally occurring methane and saline groundwater in an area of unconventional shale gas development*” published in *Geochimica et Cosmochimica Acta*, (vol. 208, p. 302-334) was selected to be the winner of the 2018 Society for Organic Petrology Dalway Swaine Award.

2019 – Paper “*Large-scale Uranium Contamination of Groundwater Resources in India*” was selected as one of the best papers for 2018 in *Environmental Science & Technology Letters*.

2019 - Recipient of the leadership award by the Water-Rock Interaction (WRI) Working Group, International Association of Geochemistry.

2019 - Named to the 2019 Highly Cited Researchers List - production of multiple highly-cited papers that rank in the top 1% by citations for field and year in Web of Science.
2020 - Named to the 2020 Highly Cited Researchers List - production of multiple highly-cited papers that rank in the top 1% by citations for field and year in Web of Science.
2020 - Named the Excellence in Review award for *Applied Geochemistry*.
2021 – Named Duke University Distinguished Professor of Environmental Quality.
2021 - Named to the 2021 Highly Cited Researchers List - production of multiple highly-cited papers that rank in the top 1% by citations for field and year in Web of Science.

AFFILIATIONS & MEMBERSHIPS

Geochemical Society, American Geophysical Union (AGU), Geological Society of America (GSA), International Association of Geochemistry (IAGC).

PROFESSIONAL SERVICE

Reviewer for dozens articles per month in Environmental Science and Technology, *Geochimica Cosmochimica Acta*, *Water Resources Research*, *Chemical Geology*, *Applied Geochemistry*, *Journal of Hydrology*, *Water Research*, *Water Quality Research of Canada*, *Aquatic Geochemistry*, *Hydrogeology Journal*, *The Science of Total Environment*, *Journal Environmental Quality*.

Reviewer for numerous NSF grants.

2018 –present Editor, *GeoHealth*, American Geophysical Union (AGU)

2015-present Editorial board of the American Chemical Society journal *Environmental Science and Technology*.

2007-2017 Associate Editor of the International Association of Geochemistry (IAGC) journal *Applied Geochemistry*.

2001-2005 Associate Editor for the American Geophysical Union (AGU) journal *Water Resources Research*.

2020 AGU Hydrological Science Award Committee.

2018 Department Seminar, Department of Geology, University of Illinois at Urbana Champaign

2018 Invited keynote speaker at the British Hydrogeologist Group in the conference “Use of the deep subsurface in the UK: what are the Implications for groundwater resources?”, London, UK, July 11-12, 2018.

2018 Invited speaker to Gordon Research Conference “Innovations at the Intersections of Aquatic Sciences: Water Quality, Health, Materials, Technologies”, Holderness, New Hampshire, June 24-29, 2018.

- 2017 Invited keynote speaker to the Opening Session of the 7th International GroundWater Conference “Groundwater Vision 2030”, New Delhi, India December 11-13, 2017.
- 2017 Seminar at School of Earth Sciences, Ohio State University, Columbus, Ohio, October 19, 2017.
- 2017 Seminar at Department of Geology and Geological Engineering, Colorado School of Mines, Golden, Colorado, September 21, 2017.
- 2017 Seminar at Utton Transboundary Resources Center, University of New Mexico, Albuquerque, NM, June 26, 2017.
- 2017 Seminar at School of Resources and Geosciences, China University of Mining and Technology, Beijing, China, June 2, 2017.
- 2017 Invited speaker at U.S. Environmental Protection Agency, Washington DC, March 1, 2017.
- 2017 Invited speaker to the session “Water Quality Lab: What the World is doing and why it matters for the water practice”, World Bank Water Week, Washington, DC., March 23, 2017.
- 2016 Invited speaker, Unconventional Gas and Oil Conference: Exploration and Production Feasibility in Brazil. Sao Paulo, Brazil, November 16-17, 2016.
- 2016 Keynote speaker, Water-Rock Interaction Symposium, Evora, Portugal, October 17-21, 2016.
- 2016 Invited talk to the Distinguished Lecturer Series, Center of Global Change Center, University of Toronto, Toronto, Canada, September 27, 2016.
- 2016 Keynote speaker at Israel Ecological Society, Tel Aviv, Israel, June 21-23, 2016.
- 2016 Invited talk at Department of Geology, University of Delaware, March 24, 2016.
- 2015 Invited speaker to the Joint US-UK workshop on Improving Understanding of Potential Environmental Impact Associated with Unconventional Hydrocarbons, National Environment Research Council (NERC) and National Science Foundation (NSF) joint workshop, Washington DC, November 5-6, 2015.
- 2015 Invited speaker in the Pardee keynote Symposia P4: Similar Information , different results: fracking from state to state, Geological Society of America, Baltimore, November 3, 2015.
- 2015 Chair of The Second Workshop on the Water-Energy Nexus in China”, Kunshan, China, October 14-15, 2015.

- 2015 Invited keynote speaker to the ICCE 2015, Leipzig, Germany, September 20, 2015.
- 2015 Theme chair “Energy Resources”, Goldshmidt Conference, Prague, Czech Republic, August 16-21, 2015.
- 2015 Chair of a session “Geochemical Characterizations of Unconventional Petroleum Reservoirs and Environmental Impacts Associated with their Production”, Goldshmidt Conference, Prague, Czech Republic, August 16-21, 2015.
- 2015 Invited speaker at the National Academy of Science workshop “Chemistry and Engineering of Shale Gas and Tight Oil Resource Development”, May 18-19, 2015 , Washington DC.
- 2014 Chair of workshop “Water-energy Nexus in China”, Kunshan, China, November 7, 2014.
- 2014 Theme chair “Hydrogeochemistry”, Goldshmidt Conference, Sacramento California, June 8-13, 2014.
- 2014 Keynote speaker in a session on shale gas development, 2014 European Union of Geoscience (EGU) meeting , Vienna, Austria, April 28-May 2, 2014.
- 2013 Keynote speaker to a session entitled “Environmental and Social Implications of Hydraulic-Fracturing–Driven Oil and Gas Development: Toward a More Holistic Assessment”, 2013 GSA Annual Meeting & Exposition, Denver, October 27-30, 2013.
- 2013 Keynote speaker to a special session (Pardee Keynote Symposia) of the Geological Society of America, entitled “Energy and Health: The Emergence of Medical Geology in Response to the Shale Gas Boom”, 2013 GSA Annual Meeting & Exposition, Denver, October 27-30, 2013.
- 2013 Testimony to the Office of Management and Budget (OMB) on new EPA’s proposed effluent limitation guidelines (ELGs) for the steam electric sector; Washington, DC, April 12, 2013.
- 2012 Chair, Pardee Symposium, Geological Society America Meeting, Charlotte, NC, USA, 4-7 Nov 2012.
- 2012 A Congressional briefing on “*Environmental Consequences of Past and Future Energy Production in the United States,*” Rayburn House Office Building., Washington DC, October 16, 2012.
- 2012 Keynote speaker to the Association of Ecosystem Research Centers (AERC) annual meeting, Washington Dc, October 16, 2012.

- 2009 A testimony to the Subcommittee on Water Resources and Environment, U.S. House of Representatives; *“The Tennessee Valley Authority’s Kingston Ash Slide: Potential Water Quality Impacts of Coal Combustion Waste Storage”*. Washington, DC, March 31, 2009.
- 2008 Keynote speaker at University Council on Water Resources/ National Institute for Water Research annual conference “ International water resources: Challenges for the 21st century” , Durham, NC, July 2008.
- 2007 Chair of a special session (Pardee Keynote Symposia) of the Geological Society of America, entitled *“Middle Eastern Water Resources in Times of Crisis”*, 2007 GSA Annual Meeting & Exposition, Denver, October 28-31, 2007.
- 2007 Chair of a session entitled *“Natural Contaminants in Groundwater Resources: Occurrence, Geochemistry, Health, and Remediation”*, American Geophysical Union (AGU), Joint Assembly Meeting, Acapulco, Mexico, May 22-25, 2007.
- 2007- present Member of the Environmental Surveillance Committee of the N.C. Radiation Protection Commission.
- 2006-2009 Principle Investigator of a USDA research project entitled *“An integrative investigation of the sources and effects of groundwater contamination for local communities and homeowners in North Carolina”*.
- 2006-2009 Investigator of a USAID (MERC) research project entitled *“The salinity curse of the Middle East fossil groundwater: The Radioactivity factor”*.
- 2006 Chair of a Workshop on *“Radon Occurrence, Health Risks and Policy, with an Emphasis on Radon in Ground Water Drinking Supplies”*, Duke University, Durham, NC, (<http://www.nicholas.duke.edu/radon/>), October 4, 2006.
- 2003 Advisor to International Atomic Energy Agency for designing Cooperation Research Project on application of isotopes in studying agricultural return flow.
- 2003 - 2004 Vice-President, International Commission on Water Quality, International Association of Hydrological Sciences.
- 2001-2004 Coordinator of the geochemistry research group of European Union Fifth Framework research BOREMED entitled *“Boron contamination of Water resources in the Mediterranean region: Distribution, Sources, Social impact and Remediation”*.
- June 2001 Invited Speaker at *Water-Rock Interaction –10* International conference, Sardinia, Italy.

- 1999-2004 Coordinator of US-AID - Middle East Regional Cooperation Research (MERC) project entitled “*Water Quality along the Jordan River and evaluation of the sources of salts*”.
- 2000 Organizer of a special workshop with the International Atomic Energy Agency, entitled “*Regional workshop on isotopes and geochemical methods in the study of water and salinization in arid region.*”
- 1999 Advisor for the design of Cooperation Research Project on application of isotopes in studying salinization, International Atomic Energy Agency, Vienna, Austria.

Duke University service

- 2016-2017 Chair of the Nicholas School of the Environment Faculty Council
- 2007- 2011 Chair of *Water and Air Resources Program* at the Nicholas School of Environment and Earth Sciences, Duke University.
- 2019-2022 Academic Programs Committee (APC), Duke University.

Member of Duke University Radioactivity Safety Committee, Duke University Misconduct committee, University Calendar Committee, Academic Council (2006-2008), Nicholas School of Environment Water Initiative Committee, and head of Search Committee for a Global Hydrology position.

PUBLICATIONS

(* research done while Vengosh’s graduate students or post-docs)

Book

Vengosh, A. and Weinthal, E. (2022) *Water Quality Impact of the Energy-Water Nexus*. Cambridge University Press (February 2022). DOI: <https://doi.org/10.1017/9781107448063>

Refereed articles in scientific journals

2024

180) Hill, R.C., Williams, G.D.Z., Wang, Z., Hu, J., El-Hasan, T.E., Duckworth, O.W., Schnug, E., Bol, R., Singh, A., Vengosh, A. (accepted). Tracing the environmental effects of mineral fertilizer application with trace elements and strontium isotope variations. *Environmental Science and Technology Letters*.

179) Zolfaghari, A., Gehman, J., Kondash, A.J., Konhauser, K.O., Ok, Y.S., Vengosh, A., Alessi (in press). Wastewater Production Footprint of Conventional and Unconventional Oil and Gas Wells in North America. *Nature Water* (in press)

178) Mukherjee, A., Coomar, P., Sarkar, S., Johannesson, K.H., Fryar, A.E., Schreiber, M.E., Ahmed, K.M., Alam, M.A., Bhattacharya, P., Bundschuh, J., Burgess, W., Chakraborty, M., Coyte, R., Farooqi, A., Guo, H., Ijumulana, J., Jeelani, G., Mondal, D., Nordstrom, D.K., Podgorski, J.,

Polya, D.A., Scanlon, B.R., Shamsudduha, M., Tapia, J., and Vengosh, A. (2024) Arsenic and other geogenic contaminants in global groundwater. *Nature Review Earth Environment*, 5, 312–328.
<https://doi.org/10.1038/s43017-024-00519-z>

2023

177) Gao, J., Zou, C., Zhang, X., Guo, W., Yu, R., Ni, Y., Liu, D., Kang, L., Liu, Y., Kondash, A.J., Vengosh, A. (2023) The water footprint of hydraulic fracturing for shale gas extraction in China. *Science of The Total Environment*, 168135. <https://doi.org/10.1016/j.scitotenv.2023.168135>

176) Hu, J.*, Wang, Z.*, Williams, G.*, Dwyer, G.S., Gatiboni, L., Duckworth, O.W., Vengosh, A. (2023). Evidence for the accumulation of toxic metal(loid)s in agricultural soils impacted from long-term application of phosphate fertilizer. *Science of The Total Environment*, 167863.
<https://doi.org/10.1016/j.scitotenv.2023.167863>

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Madrid, V., Morris, J.P., Parker, B.L., Stringfellow, W.T., Varadharajan, C. and **Vengosh, A.** (2015) Recommendations on Model Criteria for Groundwater Sampling, Testing, and Monitoring of Oil and Gas Development in California. Final Report California State Water Resources Control Board, LLNL-TR-669645, June 2015.

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Williams, G., Wang, Z., Hill, R., Vengosh, A. (2023). Potential Water Quality Impacts of Hard-Rock Lithium Mining. AGU Fall Meeting, December 2023, San Francisco, USA. (<https://agu.confex.com/agu/fm23/meetingapp.cgi/Paper/1445244>)

Hill, R., Wang, Z., Williams, G., Polyak, V.G., Kipp, M., Asmerone, Y., Vengosh, A. (2023) Reconstructing the Depositional and Diagenetic Conditions of Global Phosphate Rock Through Stable Uranium and Strontium Isotopes. AGU Fall Meeting, December 2023, San Francisco, USA. (<https://agu.confex.com/agu/fm23/meetingapp.cgi/Paper/1414905>).

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Wang, Z., Dai, S., Cowan, E.A., Dietrich, M., Schlesinger, W., Wu, Q., Zhou, M.; Seramur, K., Das, D., Vengosh, A. (2023). Fingerprints and Fluxes of Lead (Pb) from Coal Fly Ash Disposal in China, India, and the United States. Goldschmidt Conference, July 2023, Lyons, France. (<https://conf.goldschmidt.info/goldschmidt/2023/meetingapp.cgi/Paper/18233>).

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Vengosh, A., Wang, Z., Williams, G., Hill, R., Dwyer, G., Duckworth, O., Gatiboni, L., Schnug, E., Sun, Y., Bol, R., El-Hasan, T., Haneklaus, S., Bahadir, A.M., Singh, A., and Shrivastava, A. (2022). Strontium isotopes and metal(loid)s variations in global phosphate ores. Goldschmidt Conference, July 2022, Honolulu, Hawaii, USA. (<https://doi.org/10.46427/gold2022.10558>).

Vengosh, A. and Weinthal, E. (2021) The global water footprint of fossil fuels: The role of the energy-water quality nexus (invited). AGU Fall Meeting, December 2021, New Orleans, USA.

Wang, Z., Wade, A., Richter, D., Stapleton, H., Kaste, J., Vengosh, A. (2021). Soil Lead in an Urban Environment: Co-occurrence with Metal(loid)s and Fallout Radionuclides, Isotopic Fingerprint, and in vitro Bioaccessibility (invited). AGU Fall Meeting, December 2021, New Orleans, USA.

Akrie, P., Coyte, R.M., Lundstrom, C., Vengosh, A. (2021) The role of chemical reduction in reducing uranium concentrations in natural groundwaters: A case study from India. GSA Annual Meeting, October, 2021. Portland, Oregon, USA.

Vengosh, A., Ni, Y., Chen, J., Liao, F., Yao, L., Gao, J., Sui, J., Coyte, R.M. Lauer, N. (2020) Geochemical and multi-isotope tracing the origin and modification of oilfield water from Jiuquan Basin, Northwestern China. AGU Fall Meeting, (on-line), December 2020.

Coyte, R.M., Das, D., Bala, R., Mishra, V., Jain, R., Srivastava, S., Vengosh, A. (2020) Freshening and Salinization are Important Factors Controlling Concentrations of Boron and Uranium in NW Indian Groundwater. AGU Fall Meeting, (on-line), December 2020.

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Vengosh, A., Cowan E.A., Coyte, R., Kondash A.J., Wang, Z., Brandt, J.E., Dwyer, G.S. (2019) Tracing unmonitored coal ash spills in the environment. AGU Fall Meeting, San Francisco, December 2019.

Vengosh, A., Coyte, R., Fust, K.E., Mitch, W. (2019) Water quality as a limiting factor for sustainable utilization of groundwater in Northwestern India. AGU Fall Meeting, San Francisco, December 2019.

Coyte, R., Vengosh, A. (2019) Co-occurrence of four oxyanion forming elements in groundwater from the North Carolina Piedmont. AGU Fall Meeting, San Francisco, December 2019.

Wang, Z., Dwyer, G.S., Coleman, D.S., Vengosh, A. (2019) Lead isotopes in coal combustion residuals from the United States: Characterization and environmental application. AGU Fall Meeting, San Francisco, December 2019.

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Vengosh, A., Cowan E.A., Coyte, R., Kondash A.J., Wang, Z., Brandt, J.E., Dwyer, G.S. (2019) Evidence for unmonitored coal ash solid spills and impact on the environment. GSA Annual Meeting in Phoenix, Arizona, USA, 2019.

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Lauer, N., Warner, N., Vengosh, A. (2017) Using Radium Nuclides and Decay Products as Tracers and Timers of Oil and Gas Wastewater Contamination. *The 12th International Symposium on Applied Isotope Geochemistry (AIG-12)*, September 17-22, 2017, Copper Mountain, Colorado.

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Harkness, J.S., Warner, N., Kern, E., Darrah, T., Jackson R., Vengosh, A. (2015) Geochemical Characterization of West Virginia Groundwater in an Area Impacted by Hydraulic Fracturing. *Goldshmidt Conference*, August 16-21, 2015, Prague, Czech Republic.

Ni, Y., Lauer, N., Li, W., Vengosh, A. (2015) The Geochemistry and Isotopic Composition of Produced Waters from Gas Fields in Sichuan Basin, China. *Goldshmidt Conference*, August 16-21, 2015, Prague, Czech Republic.

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Deonarine, A., Hsu-Kim, H., Ruhl, L., Vengosh, A., 2010. Riverine mercury contamination after the 2008 coal ash spill at the Kingston Fossil Plant, TN. 20th Annual V.M. Goldschmidt Conference Knoxville, TN. June 21-25, 2010.

Deonarine, A., Hsu-Kim, H., Ruhl, L., Vengosh, A. 2010. Assessment of mercury and methylmercury in the Emory, Clinch and Tennessee River system after the December 2008 coal ash spill at the Kingston Fossil Plant, TN. TVA-Kingston Fly Ash Release Environmental Research Symposium, March 11-12, 2010. Harriman, TN.

Ruhl, L., Vengosh, A. & Dwyer G, 2010. Differential leaching of trace metals and their isotopes from coal combustion products. TVA-Kingston Fly Ash Release Environmental Research Symposium, March 11-12, 2010. Harriman, TN.

Ruhl, L., Vengosh, A. & Dwyer G, 2010. The impact of the Tennessee Valley Authority (TVA) coal ash spill of the quality of the Emory and Clinch Rivers: the first year evaluation TVA-Kingston Fly Ash Release Environmental Research Symposium, March 11-12, 2010. Harriman, TN.

Ruhl, L., Vengosh, A., Dwyer G, A. Deonarine; H. Hsu-Kim, 2009. Water quality monitoring of the Emory and Clinch River: the impact of the Tennessee Valley Authority coal ash spill, Kingston, TN. SETAC North America 30th Annual Meeting; Human-Environment Interactions: Understanding Change in Dynamic Systems; Hilton Riverside, New Orleans, Louisiana, USA, 19 - 23 November 2009.

Raanan, H. and Vengosh, A., 2009. Radium isotopes as natural tracers of groundwater seepage in low salinity systems. Geological Society of America, Portland, Oregon ; 18-21 October 2009; *GSA Abstracts with Programs*. Vol. 41, No. 7, p. 348.

Nunnery, A., Warner, N., Baker, P., Dwyer, G.S., Vengosh, A. Fritz, S.C., Lowenstein, T.K., Godfrey, L. and Rigsby, C.A., 2009. Climate significance of large lakes on the Bolivian Altiplano of South America. Geological Society of America, Portland, Oregon ; 18-21 October 2009; *GSA Abstracts with Programs*. Vol. 41, No. 7, p. 274.

Warner, N., Tagma, T., Bouchaou, L., Boutaleb, S., Lgourna, Z., Pankratove, I., Ettayfi, N., Hsissou, Y., Belkacim, S. and Vengosh, A. 2009. Investigation of groundwater chemistry of the western Atals and Ant-Atlas mountains in Morocco using boron, strontium, and radium isotopes. Geological Society of America, Portland, Oregon ; 18-21 October 2009; *GSA Abstracts with Programs*. Vol. 41, No. 7, p. 579.

Vinson, D.S. Lundt D.S., Vengosh, A., and Dywer, G.S., 2009. Radium in the Jordan sandstone, Minnesota: Distribution and geochemical controls in an aquifer recharged by meltwater. Geological Society of America, Portland, Oregon ; 18-21 October 2009; *GSA Abstracts with Programs*, Vol. 41, No. 7, p. 700.

Ruhl, L., Vengosh, A., and Dwyer, G.S., 2009. Boron and strontium isotope proxies for tracing the environmental impact of the TVA coal ash spill. Geological Society of America, Portland, Oregon; 18-21 October 2009; *GSA Abstracts with Programs*, Vol. 41, No. 7, p. 334.

Vengosh, A., **Ruhl, L.**, Dwyer, G.S., 2009. The isotopic imprint of coal ash impact on the environment. 8th International Symposium on Applied Isotope Geochemistry. La Malbaie, Quebec, Canada, August 30-September 4, 2009.

Vengosh, A., Dwyer, G.S., Rimawi, O., Al-Zoubi, A., Ganor, J., 2009. The origin of fossil groundwater from the Nubian sandstone aquifers in the Middle East: A multi-isotope (Ra, B, Sr, S, O, H) investigation. Goldschmidt Conference, Davos, Switzerland, June 21-26, 2009.

Vinson, D.S., Lundy, J.R., Dwyer, G.S., Vengosh, A., 2009. Coupled use of Sr and Ra isotopes to assess Ra mobility and water-rock interaction in sandstone aquifers. Goldschmidt Conference, Davos, Switzerland, June 21-26, 2009.

Vengosh, A., **Ruhl, L.**, Dwyer, G., Hsu-Kim, H., Deonaraine, A., Bergin, M., Kravchenko, J. (2009) The environmental and health effects of the coal ash spill at Kingston, Tennessee: Preliminary assessment. World of Coal ash 2009 (WOCA), Lexington, Kentucky, May 4-7, 2009.

Vengosh, A., **Vinson, S. Eigel, S. Merola, B.R.**, Pratson, E., Dwyer, G., Benneer, L.S., Klein, E., Tootoo, J., Weinthal, W.S., Wiesner, M. (2009) An integrative study of the sources and effects of naturally occurring contaminants in private wells in North Carolina: A water quality prospective. USDA-CSREES 2009 National Water Quality Conference. St. Louis, MO. February 8-12, 2009.

Dwyer, G. S. and Vengosh, A. (2008) Alternative filament loading solution for accurate analysis of boron isotopes by negative thermal ionization mass spectrometry. American Geophysical Union, Fall Meeting 2008, abstract #H51C-0824.

Vengosh, A., **Hirschfeld, D., Vinson, D.S.**, Rimawi, O., Al Zoubi, A., Marie, A., Ganor, J. Dwyer, G. S. (2008) Isotopic Tracers (Ra, Sr, O, H) for Elucidating the Sources of High Naturally Occurring Radioactive Groundwater from the Disi Aquifer, Jordan. *GSA Abstracts with Programs*, GSA, Vol. 40, No. 6, p. 120.

Raanan, H., Vengosh, A., Paytan, A., Nishri, A., and Kabala, Z. (2008) Ra Isotopes as a Tool for Quantifying Saline Groundwater Flow into a Fresh Water Lake. A Case Study from the Sea of Galilee (Lake Kinneret), Israel. *GSA Abstracts with Programs*, GSA, Vol. Vol. 40, No. 6, p. 346.

Vinson, D.S., Lundy, J.R., Dwyer, G.S. and Vengosh, A. (2008) Isotopic Indicators (^{223}Ra , ^{224}Ra , ^{226}Ra , ^{228}Ra , ^{222}Rn , $^{87}\text{Sr}/^{86}\text{Sr}$) of Radium Mobilization and Retardation In the Mt. Simon Aquifer, Minnesota. *GSA Abstracts with Programs*, GSA, Vol. 40, No. 6, p. 339.

Vengosh, A. (2007) Isotopic Reconnaissance of water quality degradation in the Middle East. Geological Society of America (GSA) Annual Meeting, Denver (28-31 October 2007); *GSA Abstracts with Programs*, GSA Vol. 39, No. 6, p. 342.

Vengosh, A. Kloppmann, W., Guerrot, C., Millot, R., Pankratov, I. (2007). The isotopic composition of man-made fresh water: Seawater and brackish groundwater reverse osmosis desalination. Geological Society of America (GSA) Annual Meeting, Denver (28-31 October 2007); *GSA Abstracts with Programs*, Vol. 39, No. 6, p. 114.

Vinson, D.H., Hirsschfled, D., Dwyer, G. and Vengosh, A. (2007) Radium and radon in fresh groundwater: Insights along solute and redox gradients in the North Carolina Piedmont. Geological

Society of America (GSA) Annual Meeting, Denver (28-31 October 2007); *GSA Abstracts with Programs*, Vol. 39, No. 6, p. 178.

Raanan, H., Vengosh, A., Nishri, A., Paytan, A. (2007) radium isotopes as a proxy for groundwater-fresh water lake interaction: A case study from the Sea of Galilee, Israel. Geological Society of America (GSA) Annual Meeting, Denver (28-31 October 2007); *GSA Abstracts with Programs*, Vol. 39, No. 6, p. 479.

Vengosh, A., **Peri, N.**, Haquin, G., Paytan, A., Pankratov, I., Elhanani, S., Karpas, Z. (2007) Mechanisms of Radium Mobilization for Radium-Rich Groundwater from the Nubian Sandstone and Carbonate Aquifers in the Negev, Israel: Implications for Fossil Groundwater Resources in the Middle East. American Geophysical Union, Joint Assembly, Acapulco, Mexico, May 22-35, 2007.

Vengosh, A. Campbell, T., **Vinson, D.**, Klein, E., Dwyer, G., Benneer, L., Weinthal, E., Wiesner, M., Pratson, E. and Miranda, M.L. (2006) Natural contaminants in private wells in North Carolina. USDA-CSREES 2007 National Water Quality Conference. January 28-February 1, 2007 Savannah, Georgia.

Vinson, D.H., Campbell, T.R., Field, R.W., and Vengosh, A. (2006) Transfer of radon from groundwater into homes and the contribution of showering to indoor radon: Policy implications for unregulated private well owners at the intersection of geology and health in the North Carolina Blue Ridge. Geological Society of America *Abstracts with Programs*, Vol. 38, No. 7, p. 122. 2006 Philadelphia Annual Meeting (22–25 October 2006).

Vengosh, A., **Pery, N.**, Paytan, A. Haquin, G., Elhanany, S. and Pankratov I. (2005). Sources, mechanisms, and implications for natural radionuclide contamination in groundwater basins in the Middle East. Geological Society of America, Salt lake City, Utah, October 2005.

Vengosh, A., **Pery, N.**, Paytan, A. Haquin, G., Elhanany, S. and Pankratov I. (2004). Tracing the Origin of Radioactivity in Groundwater from the Negev, Israel. American Geophysical Union, San Francisco, December 2004.

Vengosh, A., **Hening, S.**, Ganor, J., Bullen, T.D., Weyhenmeyer, C.E., Sturchio, N.C., and Paytan, A. (2004). The origin and age of groundwater in the Nubian Sandstone aquifer in the Negev, Israel, in Wanty, R.B., and Seal, R.R., II, eds., *Water Rock Interaction*, v. 1, Proceedings of the Eleventh International Symposium on Water-Rock Interaction, Saratoga Springs, New York, July 2004: New York, A.A. Balkema, p. 509-512.

Vengosh, A. Weinthal, E., Marei, A., Gutierrez, A., Kloppmann, W. (2003). Addressing the Water Crisis in the Gaza Strip: Integration of Geochemistry, Numerical modeling, and Policy. American Geological Society, Seattle, Washington, USA. November 2-5, 2003.

Vengosh, A., Marei, A., Guerrot, C., Pankratov, I. (2002). An enigmatic salinity source in the Mediterranean coastal aquifer and Gaza Strip: Utilization of isotopic (B, Sr, O) constraints for searching the sources of groundwater contamination. Goldschmidt Conference, Davos, Switzerland, August 18-23, 2002. *Geochim. Cosmochim. Acta*, **66**, A804.

Farber, E., Vengosh, A., Shavit, U., **Holtzman, R., Segal, M.,** Gavrieli, I., and Bullen, T. (2002). Exploring the Sources of the salinity in the Lower Jordan River. International symposium on the Geochemistry of the Earth's Surface (GES-6). Honolulu, Hawaii, May 2002, Abstracts Volume Sixth, 135-155 pp.

Vengosh, A., **Farber, E.,** Shavit, U., Holtzman, R., Segal, M., Gavrieli, I., Bullen, T.M., and Mayer, B. (2001). What Science can contribute for future cooperation in the Middle East: The Jordan River. American Water Resources Association, International Specialty Conference on Globalization and Water management: the Changing Value of Water. August 6-8 2001, Dandee, Scotland, UK.

Vengosh, A., **Farber, E.,** Shavit, U., **Holtzman, R., Segal, M.,** Gavrieli, I., Bullen, T.M., (2001). *Exploring the sources of salinity in the Middle East: A hydrologic, geochemical and isotopic study of the Jordan River.* In: Cidu, R., Proceeding of the Tenth International Symposium on Water-Rock Interaction, WRI-10, Villasimuis, Sardinia, Italy, June 2001, (keynote lecture), Vol. 1, 71-79, A.A. Balkema Publishers.

Vengosh, A., **Farber, E.,** Shavit, U., Holtzman, R., Segal, M., Gavrieli, I., Bullen, T.M., and Mayer, B. (2001). *Tracing the origin of salinity of the Jordan River.* 4th International Symposium on Applied Isotope Geochemistry, June 25-29, 2001, Pacific Grove, California, USA, pp. 162-164.

Vengosh, A., Kolodny Y. and A.J. Spivack (1998) *Ground-water pollution determined by boron isotope systematics.* In: '*Application of isotopic techniques to investigate groundwater pollution*', Cooperation Research Program, The International Atomic Energy Agency (IAEA), IAEA-TECDOC-1046, pp. 17-37, October 1998, Vienna.

Vengosh A. (1992). *Boron isotope variations during brine evolution and water-rock interaction.* Kharaka Y.K. and Maest A.S. (eds.), Proceedings of the 7th International Symposium on Water-Rock Interaction, Park City, Utah, 1992. A.A. Balkema , Rotterdam, p. 693-696.

TEACHING

Courses at Duke University: Introduction to Hydrogeology (EOS123), International Water Resources (EOS227), Stable and Radioactive Isotopes in Environmental Sciences (EOS271), Water Seminar (EOS226), Water Sciences (ECS220), Water Quality and Health (ECS524) .

Graduate students:

Duke University:

- Robert Hill (PhD, 2021 -)
- Gordon Williams (PhD, 2020 -)
- Sam Saltman ((Master of Environmental management, 2021-2023) *Laboratory Experiments to Evaluate the Potential Mobilization of Contaminants from Hard Rock Lithium Mining*
- Jun Hu (Master of Environmental management, 2021-2023) *Accumulation and Distribution of Trace Elements and Radionuclides in Agricultural Soils Impacted from Long-term Phosphate Fertilizer Application.*

- Zhen Wang (PhD, 2018 -2023). *Tracing Anthropogenic Metal(oid) Contaminants in the Environment Using Geochemical, Radiogenic, and Radioactive Isotopic Tools.*
- Rachel Weinberg (Master of Environmental management, 2019-2021). *Water quality implications of the neutralization of acid mine drainage with coal fly ash from India and the United States.*
- Rachel Coyte (PhD, 2016-2021) PhD thesis: *Redox-sensitive elements in water resources.*
- Andrew Kondash (PhD, 2014 -2019) PhD thesis: *The water-energy nexus of hydraulic fracturing.*
- Nancy Lauer (PhD, 2013 -2018) PhD thesis: *Radioactivity of fossil fuel waste products and associated environmental implications*
- Jennie Harkness (PhD, 2013 -2017) PhD thesis: *Identifying water contamination from fossil fuel development using geochemical and isotopic fingerprints*
- Hadas Raanan (PhD, 2005-2011). PhD thesis: *Radium isotope geochemistry as a tracer for groundwater-surface water interaction.*
- David Vinson (PhD, 2005-2011). PhD thesis: *The impact of salinity and water chemistry on radium mobilization in groundwater systems.*
- Nathanel Warner: (PhD, 2008-2013). PhD thesis: *Tracing the origin of salinization and radium contamination in water resources of Morocco.*
- Laura Ruhl (PgD, 2008-2012). PhD thesis: *The geochemistry and isotopic characterization of coal ash and its impact on the environment.*
- Brittany R. Merola (PhD-2010 -2014). PhD thesis: *Biomarkers of arsenic and fluoride from contaminated water resources.*
- Mengjun You (Master of Environmental management, 2013-2015). *Water availability for shale gas development in Sichuan Basin, China.*
- Daniella Hirschfeld (Master of Environmental management, 2006-2008). Research topic: *Radium isotopes in groundwater in Jordan.*
- Kristen Tull (Master of Environmental management, 2006-2008). Research topic: *Mini-Superfund" Site in Kawerau, New Zealand: A Closer Look at Water Quality.*
- Britany R. Merola (Master of Environmental management, 2007-2009). Research topic: *Arsenic Exposure from Groundwater in Union County, North Carolina.*
- Heidi Hausman (Master of Environmental management, 2007-2009). Research topic: *Responsible Development in Tulum, Mexico: Considering Water Quality and Subaqueous Cave Locations.*

Ben Gurion University:

- Efrat Farber (PhD, 2000-2005). PhD thesis: *The lower Jordan River: river salinization, relationship with adjacent groundwater and future management.*
- Yohanan Artzi (M.Sc., 1999-2003) Research topic: *The origin of salinity in the coastal aquifer of Israel.*
- Osnat Velder (M.Sc., 2000-2003) Research topic: *Mapping of oxygen isotopes and salinity in groundwater from the coastal aquifer of Israel.*
- Sharona Henig (M.Sc., 2002-2004) Research topic: *Geochemical and isotopic (oxygen, hydrogen, boron, and strontium) characterization of groundwater from the Kurnub Group aquifer in the Negev and the Arava Valley, Israel.*
- Dana Roded (M.Sc., 2003-2005) Research topic: *Identification of the origin of nitrate pollution in the coastal aquifer by isotopic traces.*

- Nitzan Pery (M.Sc., 2003-2005) Research topic: *Radioactivity in groundwater from the Negev, Israel.*

AWARDS AND GRANTS

Duke University

- 2023-2025 North Carolina Water Research Institute. Vengosh, A. (PI). *Potential impacts of lithium mining on water quality in North Carolina* (\$120,000).
- 2023-2026 National Science Foundation. Vengosh, A. (PI), Gatiboni, L.C. (co-PI). Collaborative Research: *From Global to Local: Geochemistry of Global Phosphate Ores and Implications for Tracing the Environmental Impacts of Fertilizers Utilization* (EAR- 2305946) (\$433,480).
- 2023-2024 Duke University Climate Research Innovation Seed Program (CRISP). Vengosh, A. (PI), Weinthal, E. (co-PI), Meyer, J. (co-PI). *The Environmental, Health, and Justice Implications Associated with Mining of Critical Raw Materials* (\$100,000).
- 2023-204 Duke University Trent Foundation. Vengosh, A. (PI). *Water availability and Environmental Implications from Future Lithium Mining in Bolivia* (\$10,000).
- 2023-2025 Albemarle Ltd. Vengosh, A. (PI), Shiendel, D. (co-PI). *The Potential Environmental Effects of Lithium Mining and Extraction.* (\$622,212).
- 2022-2027 National Institute of Health (NIH). Stepleton, H (PI), Hsu-Kim (co-PI), Vengosh (co-PI). *Project 1: Prenatal Exposures to PAHs and Metals in an Impacted Community: Assessing Neurodevelopment Impacts and Tracing Metal Sources.* (Total \$1,755,459)
- 2021-2023 India Minsitry of Coal. Das, D. (PI), Vengosh, A. (co-PI), *Assessment of Rare Earth Elements (REE) and other economic resources in Coal & Non-Coal Strata and Characterization of Acid Mine Drainage and its pollution control from the North Eastern Region (NER) Coalfield, India* (\$57,000 for Duke).
- 2020-2023 National Science Foundation. Vengosh, A. (PI), Cowan, E.A. (co-PI). *Collaborative Research: Tracing Coal Ash Solids in the Environment - Implications for long-term contamination of the aquatic ecosystem.* (EAR-1932649) (\$220,365).
- 2022-2024 U.S. Geological Srvey, Vengosh (PI) *Isotope measurements of oil and gas produced water in California* (\$88,600)
- 2020-2021 Duke Energy Initiative Seed Funding. Vengosh, A. (PI), Bejan, A. (co-PI). *The Energy-Water Nexus in India: Novel Solutions to Meet Energy and Water Needs.* (\$45,000).

- 2020-2022 Earthjustice. Vengosh, A. (PI). *The Chemistry, NORM, and Quality of Coal Combustion Residuals from India*. (\$30,000).
- 2018-2021 PetroChina, China. Vengosh A. (PI). Geochemical characteristics of formation water in China (\$115,000)
- 2018-2019 Duke University India Initiative. Vengosh, A. (PI). *An Assessment of the Water Quality in Northwestern India: A Multi-Component Characterization of Pollutants in Drinking Water and Remediation Strategies* (\$18,000).
- 2017-2019 National Science Foundation Exploratory Research (EAGER). Vengosh, A. (PI). *SusChem: EAGER – The occurrence and distribution of hexavalent chromium and other contaminants in groundwater from aquifers of the eastern United States*. (\$137,657) (EAR-1733637).
- 2017-2018 Duke University Global Enhancement Fund. Vengosh (PI) *Water Quality and Health in Northwestern India* (\$25,000).
- 2016-2018 North Carolina Water Research Institute. Vengosh, A. (PI). *Tracing Groundwater Contamination Near And Away From Coal Ash Ponds in North Carolina* (\$100,000).
- 2017 -2020 U.S. Department of Agriculture (USDA) National Institute of Food and Agriculture (NIFA)/Agriculture and Food Research Initiative (AFRI)/ Water for Agriculture. Vengosh, A. (PI), Weinthal E. (Co-PI), Elisabetta Lambertini (co-PI), Jennifer Hoponick Redmon (co-PI). *Assessing potential human health impacts associated with the use of oilfield produced water for crop irrigation”* (\$500,000).
- 2017-2018 PetroChina, China. Vengosh A. (PI). *The Geochemistry and quality of flowback water from shale gas wells in Sichuan Basin, China* (\$208,500).
- 2016-2020 U.S. Geological Survey. Vengosh A., (PI). *Isotope measurements of oil and gas produced water in California* (\$400,000).
- 2016-2017 Park Foendation. Vengosh, A. (PI) *Trace metals contamination from oil and gas wastes in New York and Pennsylvaniam* (\$60,000).
- 2016-2017 North Carolina Water Research Institute, Vengosh (PI). *Tracing Groundwater Contamination Near And Away From Coal Ash Ponds in North Carolina* (\$100,000).
- 2016-2017 National Insitution of Health (NIH), National Institute of Environmental Health Sciences, Nagel, S. University of Missouri (PI), Vengosh, A. (co-PI). *Endocrine disrupting activity associated with hydraulic fracturing* (\$427,273).
- 2015-2016 Southern Environmental Law Center. Vengosh, A. (PI). *Applying geochemical tracers for elucidating the leaking of coal ash ponds*. (\$60,000).
- 2015-2016 Park Foundation. Vengosh, A. (PI), *Radioactivity and Isotopic Markers of Oil and Gas Liquid and solid Wastes in New York and Pennsylvania* (\$60,000).

- 2014-2017 National Science Foundation. Vengosh (PI), Jackson R.B., Darrah, T. *SusChEM: Geochemical Characterization and Evaluation of the Environmental Impacts of Hydraulic Fracturing Fluids* (\$364,100) (EAR-1441497).
- 2014-2015 Park Foundation. Vengosh, A. (PI), Jackson R.B., Plata, D. *The environmental and health risks of oil and gas wastewater in New York and Pennsylvania* (\$70,000).
- 2014-2015 Duke Energy Initiative. Vengosh, A., Weinthal, E., Dalia Patino-Echeverri, Marc Deshusses. *A global perspective of water scarcity and unconventional shale gas development* (\$40,000).
- 2013-2014 National Science Foundation Exploratory Research (EAGER). Darrah, T. (PI), Vengosh, A., Jackson J. *A novel geochemical approach for environmental risk assessment of stray gas contamination in shallow aquifers within active and prospective shale gas development zones* (\$100,000). (EAR-1249255)
- 2013-2014 Park Foundation. Vengosh, A. (PI), Jackson R.B., Plata, D. *The environmental effects of oil and gas wastewater disposal in New York and Pennsylvania* (\$70,000).
- 2013-2017 National Science Foundation. Ferguson, L. (PI), Wiesner, M., Tarabara, V., Bang, J., Plata, D., Hsu-Kim, H., Gunsch, C., Seshusses, M., Vengosh, A., Golden, J. *PIRE: Water and Commerce: Technologies to enable environmental sustainability in global markets* (\$4,750,443).
- 2012-2015 National Science Foundation. Hsu-Kim, H. (PI), Vengosh, A., Hower, J. *Characterization of contaminants and isotopic tracers associated with coal combustion products* (\$301,000).
- 2011-2012 Park Foundation. Jackson, R.B. (PI), Vengosh, A. *Impact of Gas Drilling and Hydraulic Fracturing on Water Quality* (\$50,000)
- 2012-2013 North Carolina Water Resources Research Insitute. Jackson, R.B. (PI), Vengosh, A. *Baseline groundwater quality sampling in parts of Lee and Chatham Counties, North Carolina.* (\$50,000).
- 2011-2012 Duke University - Problem-Focused Interdisciplinary Research-Scholarship Teams (PFIRST). Jeuland, M., Vengosh, A., Weinthal, E., McCornick, O. Crump, J. and Krauchanka, J. *Understanding linkages between climate change, water resources, and health in Ethiopia* (\$30,000)
- 2011-2012 National Science Foundation. Vengosh, A. (PI), Jackson, R. Weinthal, E. *Environmental and social implications of hydraulic fracturing and gas drilling in the United States: An integrative science and policy workshop* (\$45,000)
- 2011-2012 Duke Cancer Institute. Vengosh, A. (PI), Krauchanka, Y. *Environmental contaminants in drinking water from rural communities of Union county, North*

- Carolina: an integrated approach for evaluation of biomarkers of human exposure to arsenic and trace metals.* (\$50,000)
- 2011-2012 North Carolina Water Resources Research Institute. Vengosh, A. (PI), Hsu-Kim, H. *The impact of coal combustion products on the quality of water resources in North Carolina.* (\$50,000)
- 2010-2013 Oak Ridge Associated Universities. Vengosh, A. (PI), Hsu-Kim, H., Hower, J., Johnson, T. *Geochemical and isotope characterization of TVA coal combustion products: Identification of contaminants and modeling their fate in the environment.* (\$357,115).
- 2010-2011 Duke Global Health Institute. McCornick, P. and Vengosh, A. *Processes controlling groundwater quality and impacts on human health in the Main Ethiopian Rift.* (\$50,000).
- 2010-2013 DOE. Rob Jackson (PI), Avner Vengosh, Mark Little. *The Potential Risks of Freshwater Aquifer Contamination with Geosequestration Simulation and Risk Assessment of Carbon Capture and Storage (CCS).* (\$298,304).
- 2009-2010 National Science Foundation. Vengosh, A. (PI), Backer, P., Dywer, G.S. and Hsu-Kim, H. Title: *Environmental effects of the coal ash spill and remediation at Kingston, Tennessee* (\$105,000).
- 2009 Fred and Alice Stanback gift to the Nicholas School of Environment. Vengosh, A. (PI). Seed funding *The Environmental and Health Effects of the coal ash spill at Kingston, Tennessee* (\$50,000).
- 2008-2012 NATO Science for Peace and Security Program. Vengosh A. (PI) and Bouchaou, L. *Investigating salinity and radioactivity in water resources in Morocco.* (EUR 234,000).
- 2008-2009 Center of Global Change, Duke University. Vengosh, A. (PI) Jackson, R. Hsu-Kim, H. Emily S. Bernhardt, E.S. *The drought effect on water availability and quality of North Carolina water resources: Groundwater-surface water interaction and contributions of recycled wastewater* (\$50,000)
- 2007-2009 Kuwait Institute for Scientific Research (KISR). Vengosh, A. (PI). *Radium isotopes in the Persian Gulf and associated groundwater.* (\$30,000).
- 2007-2008 Health Research Council of New Zealand, Hikuroa, D. and Vengosh. A. (PI's); *“Preliminary investigation of the link between naturally occurring contaminants and health in Tarawera Valley, New Zealand”;* (\$5,000).
- 2006-2009 United States Department of Agriculture (USDA). Vengosh, A. (PI), Klein, E. Benneer, L., Weinthal, E. Wiesner, M., Mirenda M. *An integrative investigation of the sources and effects of groundwater contamination for local communities and homeowners in North Carolina* (\$570,000).

- 2006-2009 United States Agency for International Development (US-AID), Middle East Research Program (MERC). Ganor, J. (PI), Vengosh, A. , Marie, A. Rimawi, O. (PIs). *The salinity curse of the Middle East fossil groundwater: The Radioactivity factor* (\$500,000).
- 2005-2006 Cancer and the Environment: Seed Funding Award of Duke Comprehensive Cancer Center and Nicholas School of the Environment, Duke University. Avner Vengosh (PI), James J. Vredenburg, Jennifer Garst, Richard Di Giulio, Lincoln Pratson, and Emily M. Klein.
"The Link Between Environmental Radon and Cancer: A Pilot Study For a New Biogeochemical Tracer and Geographical Relationships" (\$25,000).

Ben Gurion University, Beer Sheva, Israel

- 2003-2004 Blaustein Visiting Scholar award, School of Earth Sciences, Stanford University, California, USA.
- 2002-2005 United States States Agency for International Development (US-AID), Middle East Research Program (MERC). Vengosh, A. (PI), U. Shavit, I. Gavrieli, E. Salameh, R. Daud, A. Marie. *"Water Quality along the Jordan River and evaluation of the sources of salts: Phase Two"* (\$499,000)
- 2001-2004 Water Commission, Israel. Vengosh, A.
"Using isotopic tracers for elucidating the sources and mechanism of nitrate pollution of groundwater from the coastal aquifer of Israel" (300,000 NIS).
- 2001-2004 European Community: FP5 program" Energy, Environment and Sustainable Development", "Sustainable Management and Quality of Water". Kloppmann, W., Vengosh, A. et al., *"Boron contamination of Water resources in the Mediterranean region: Distribution, Sources, Social impact and Remediation"* (Euro 1,200,000 for the total project, Euro 120,000 for BGU).
- 2000-2003 International Atomic Energy Agency, Research Co-operation Projects, Y. Ganor and A. Vengosh, *"Boron and strontium isotopic compositions of ground water from the Lower Cretaceous Kurnob sandstone: Geochemical characterization of inland saline ground water"* (\$15,000)
- 1999-2003 United States Agency for International Development (US-AID), Middle East Research Program (MERC). Vengosh, A. (PI), U. Shavit, I. Gavrieli, E. Salameh, R. Daud, A. Marie. *"Water Quality along the Jordan River and evaluation of the sources of salts: A geochemical prospective"* (\$499,000)
- 1999-2002 International Atomic Energy Agency, Research Co-operation Projects, Vengosh, A. *"Environmental Isotopes, Boron, and Bromide Variations in the Coastal Aquifer of Israel: The Impact of Long-term Exploitation"*

(\$18,000).

- 1999-2000 Department of Energy, Lawrence Livermore National Laboratory. Vengosh, A., Marie, A., "*The Mediterranean Coastal aquifer and the Shallow Aquifer System in Jericho area*" (\$12,000).
- 1998-2001 Ministry of Science, Israel. I. Gavrieli (PI), Y. Yechieli, A. Vengosh, A. Starinsky, "*Dating and geochemical characterization of shallow ground water from the coastal aquifer of Israel*". (\$190,000)

Hydrological Service, Jerusalem, Israel

- 1997-1998 University of California Water Resources. J. Gill and A. Vengosh. "*Multi-isotope investigation of ground water contamination in Salinas Valley, California*". (\$25,000).
- 1995 –1998 Israel Academy of Science. I. Gavrieli (PI), A. Starinsky (PI), A. Vengosh, A. Ayalon. "*Boron, sulfur, strontium, oxygen, and hydrogen isotopes in freshwater of a carbonate aquifer: Judea Mountain, Israel*". (\$140,000).
- 1996 - 1998 Water Commission Research grants. A. Starinsky and A. Vengosh. "*Relationships between contaminates and salinity in the coastal aquifer of Israel* (210,000 NIS)
- 1995 -1997 International Atomic Energy Agency (IAEA). Y. Kolodny and A. Vengosh. "*Boron isotope investigations of polluted groundwater and contamination sources: Establishing the rules of the game*" (\$12,000).
- 1992 - 1995 The German-Israeli Cooperative Grant (BMFT and MOST). A. Vengosh, R. Keren, K.G. Heumann (PI's). "*The influence of the coastal aquifer rocks on groundwater composition and contamination*". (148,000 DM).
- 1993 - 1995 The Ashdod-Yavneh Regional Association for Environmental Protection. A. Vengosh. "*Sources of Salinization of Groundwater from Gan Yavne-Gedera-Ashdod Area, the Coastal Plain Aquifer, Israel*" (100,000 NIS).
- 1993 - 1996 Water Commission Research grants. Y. Yechieli, (PI), D. Ronen, and A. Vengosh. "*Isotopic measurements and dating of intrusion of saline groundwater at the interface zone, the Coastal Plain Aquifer of Israel*". (160,000 NIS).
- 1993 - 1996 Water Commission Research grants. A. Starinsky and A. Vengosh. "*A survey of natural isotopic and chemical tracers in groundwater from Yarqon-Taninim aquifer as indicators for salinization*" (210,000 NIS).
- 1991 - 1994 Water Commission Research grants. E. Mazor and A. Vengosh. "*A conceptual model for aquifer systems in the coastal plain of Israel: A pilot study along Tel Aviv-Judea Mountain*" (240,000 NIS).

1986 – 1990 Research School of earth Sciences, The Australian National University, Canberra, Australia. Ph.D. Scholarship for Avner Vengosh.

Media:

Hundreds of news items, NPR and TV covers of topics related to hydraulic fracturing and water quality, coal ash, radioactivity and environmental contamination, water footprint of hydraulic fracturing, and hexavalent chromium contamination. For more details see: <http://sites.nicholas.duke.edu/avnervengosh/>)

List of Publications of Avner Vengosh on oil produced waters

- 1) Whyte, C.J., Vengosh, A., Warner, N.R., Jackson, R.B., Muehlenbachs, K., Schwartz, F.W., Darrah, T.H. (2021) Geochemical evidence for fugitive gas contamination and associated water quality changes in drinking-water wells from Parker County, Texas. *Science of The Total Environment*, 146555.
<https://doi.org/10.1016/j.scitotenv.2021.146555>
- 2) Kassotis, C.D., Harkness, J.S., Vo, P.H., Danh C. Vu, D.C., Hoffman, K., Cinnamon, K.M., Cornelius-Green, J.N., Vengosh, A., Lin, C-H., Tillitt, D.E. Robin L. Kruse, R.L., McElroy, J.A. and Nagel, S.C. (2020). Endocrine disrupting activities and geochemistry of water resources associated with unconventional oil and gas activity. *Science of the Total Environment*, 142236.
- 3) Kondash, A.J., Redmon, J.H., Lambertini, E., Feinstein, L., Weinthal, E., Cabrales, L., Vengosh, A. (2020) The impact of using low-saline oilfield produced water for irrigation on water and soil quality in California. *Science of the Total Environment*, 733, 139392.
- 4) Kondash, A.J., Patino-Echeverri, D., Vengosh, A. (2019) Quantification of the water-use reduction associated with the transition from coal to natural gas in the U.S. electricity sector. *Environmental Research Letters*, 14, 124028.
- 5) McMahon, P.; Vengosh, A.; Davis, T.; Landon, M.; Tyne, R.; Wright, M.; Kulongoski, J.; Hunt, A.; Barry, P.; Kondash, A.; Wang, Z.; Ballentine, C. (2019). Occurrence and sources of radium in groundwater associated with oil fields in the southern San Joaquin Valley, California. *Environmental Science & Technology*, 53, 16, 9398-9406.
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- 7) McMahon, P.B., Kulongoski, J.T., Vengosh, A., Cozzarelli, I.M., Landon, M.K., Kharaka, Y.K., Gillespie, J.M., Davis, T.A. (2018) Regional patterns in the geochemistry of oil-field water, southern San Joaquin Valley, California, USA. *Applied Geochemistry*, 98, 127-140.
- 8) Kondash, A.J., Lauer, N.E., Vengosh, A. (2018) The intensification of the water footprint of hydraulic fracturing. *Science Advances*, 4, (8), eaar5982; DOI: 10.1126/sciadv.aar5982. *Science Advances_ intensification of the water footprint of Hydraulic fracturing.*
- 9) Lauer, N.E., Warner, N.R., Vengosh, A. (2018) Sources of radium accumulation in stream sediments near disposal sites in Pennsylvania: Implications for disposal of conventional oil and gas wastewater. *Environmental Science & Technology*, 52(3), 955–962.
- 10) Kreuzer, R.L., Darrah, T.H., Grove, B.S., Moore, M.T., Warner, N.R., Eymold, W.K., Whyte, C.J., Mitra, G., Jackson, R.B., Vengosh, A., Poreda, R.J. (2018). Structural and hydrogeological controls on hydrocarbon and brine migration into drinking water aquifers in southern New York. *Groundwater*. Vol. 56(2) doi: 10.1111/gwat.12638. *Groundwater quality monitoring in New York*
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- 12) Neville, K.J., Baka, J., Gamper-Rabindran, S., Bakker, K., Andreasson, S., Vengosh, A., Lin, A., Nem Singh, J., Weinthal, E. (2017) Debating Unconventional Energy: Social, Political, and Economic Implications. *Annual Review of Environment and Resources*, 42, 2.1-2.26 (DOI: 10.1146/annurev-environ-102016-061102). *annurev-environ_Debating fracking Review*
 - 13) Harkness, J.S., Darrah, T.H., Warner, N.R., Whyte, C.J., Myles T. Moore, M.T., Millot, R., Kloppman, W., Jacksone, R.B., Vengosh, A. (2017) The Geochemistry of Naturally Occurring Methane and Saline Groundwa in an Area of Unconventional Shale Gas Development. *Geochimica et Cosmochimica Acta*, 208, 302-334. *GCA_Groundwater in WV*.
 - 14) Vengosh, A., Kondash, A., Harkness, J., Lauer, N., Warner, N., Darrah, T.H. (2017) The Geochemistry of Hydraulic Fracturing Fluids. *Procedia Earth and Planetary Science*, 17, 21-24. The geochemistry of fracking fluids.
 - 15) Kondash, A.J., Albright, E., Vengosh, A. (2017) Quantity of Flowback and Produced Waters from Unconventional Oil and Gas Exploration. *Science of the Total Environment*, 574C, 314-321. *quantity-and-source-of-unconventional-wastewater*.
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