Impact of Shale Gas Development on Regional Water Quality

R. D. Vidic,[1]* S. L. Brantley,[2] J. M. Vandenbossche,[1] D. Yoxtheimer,[2] J. D. Abad[1]

Background: Natural gas has recently emerged as a relatively clean energy source that offers the opportunity for a number of regions around the world to reduce their reliance on energy imports. It can also serve as a transition fuel that will allow for the shift from coal to renewable energy resources while helping to reduce the emissions of CO_2, criteria pollutants, and mercury by the power sector. Horizontal drilling and hydraulic fracturing make the extraction of tightly bound natural gas from shale formations economically feasible. These technologies are not free from environmental risks, however, especially those related to regional water quality, such as gas migration, contaminant transport through induced and natural fractures, wastewater discharge, and accidental spills. The focus of this Review is on the current understanding of these environmental issues.

Advances: The most common problem with well construction is a faulty seal that is emplaced to prevent gas migration into shallow groundwater. The incidence rate of seal problems in unconventional gas wells is relatively low (1 to 3%), but there is a substantial controversy whether the methane detected in private groundwater wells in the area where drilling for unconventional gas is ongoing was caused by well drilling or natural processes. It is difficult to resolve this issue because many areas have long had sources of methane unrelated to hydraulic fracturing, and pre-drilling baseline data are often unavailable.

Water management for unconventional shale gas extraction is one of the key issues that will dominate environmental debate surrounding the gas industry. Reuse of produced water for hydraulic fracturing is currently addressing the concerns regarding the vast quantities of contaminants that are brought to the surface. As these well fields mature and the opportunities for wastewater reuse diminish, the need to find alternative management strategies for this wastewater will likely intensify.

Outlook: Improved understanding of the fate and transport of contaminants of concern and increased long-term monitoring and data dissemination will help effectively manage water-quality risks associated with unconventional gas industry today and in the future. Confidentiality requirements dictated by legal investigations combined with the expedited rate of development and the limited funding for research are major impediments to peer-reviewed research into environmental impacts. Now is the time to work on these environmental issues to avoid an adverse environmental legacy similar to that from abandoned coal mine discharges in Pennsylvania.

Drilling multiple horizontal wells from a single well pad allows access to as much as 1 square mile of shale that is located more than a mile below. [Image courtesy of Range Resources Appalachia]

READ THE FULL ARTICLE ONLINE
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ARTICLE OUTLINE

BACKGROUND READING

General overview that includes geology of major shale plays, description of the extraction process, relevant regulations, and environmental considerations: www.netl.doe.gov/technologies/oil-gas/publications/EPreports/Shale_Gas_Primer_2009.pdf

Detailed information about individual shale gas wells, including chemical additives used in each hydraulic fracturing treatment: http://fracfocus.org

Findings of the U.S. Environmental Protection Agency study on the potential impact of hydraulic fracturing on drinking water resources: www.epa.gov/hfstudy

Comprehensive information from the British Geological Survey about shale gas (including articles and videos): www.bgs.ac.uk/shalegas

Site developed in collaboration with the Geological Society of America promoting the rational debate about energy future: www.switchenergyproject.com

Latest news and findings about shale gas. www.shale-gas-information-platform.org

[1]Department of Civil and Environmental Engineering, University of Pittsburgh, Pittsburgh, PA 15261, USA. [2]Earth and Environmental Systems Institute and Department of Geosciences, Pennsylvania State University, University Park, PA 16802, USA.
*Corresponding author. E-mail: vidic@pitt.edu

RETROSPECTIVE

Robert G. Edwards (1925–2013)

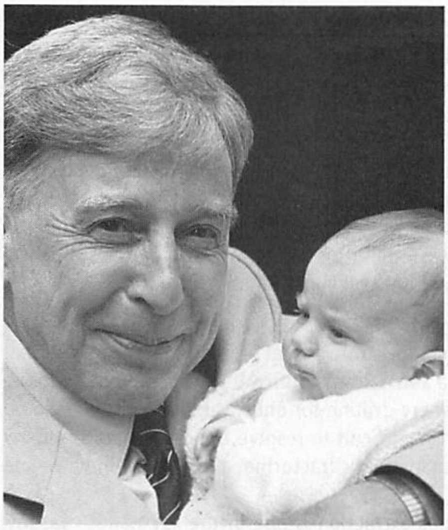
The work of a pioneer of in vitro fertilization led to the first "test-tube baby" and changed the field of human reproductive biology.

Susan J. Fisher[1,2] and Linda C. Giudice[1,2,3]

Robert G. Edwards, who with his colleagues Patrick Steptoe and Jean Purdy enabled the birth of the first "test tube" baby, died on 10 April at his home near Cambridge University in England. He was 87. In 2010, he was awarded the Nobel Prize in Physiology or Medicine for the team's work, ushering in the era of in vitro fertilization (IVF), which allows infertile couples to have their own biological children. The societal impact of this revolution in human reproduction has been enormous. An estimated 5 million babies have been born as the result of assisted reproductive technologies, a number that will doubtless increase as a result of delayed childbearing. Sadly, due to failing health and dementia, Edwards was unable to attend the Nobel award ceremony, and it is unlikely that he even knew of this great recognition. His wife, Ruth Fowler Edwards (they met as graduate students), and former trainee, Martin H. Johnson, addressed the audience on his behalf, a cruel irony given the unbridled passion with which he spoke and wrote about his work on human reproduction.

Robert Geoffrey Edwards was born in 1925 in Yorkshire, England. He attended the University of Wales and then earned a Ph.D. in physiology from the University of Edinburgh in 1955. He joined the University of Cambridge faculty in 1963 where he remained for the rest of his career. The notion that human IVF was possible first occurred to Edwards during his graduate work. He realized he could do nothing to help infertile couples until human oocytes (egg cells) were fertilized in vitro. In 1965, after two disappointing years, he coaxed ovarian tissue that had been removed from patients to produce several oocytes. As he described in a *Nature Medicine* article in 2001, after receiving the prestigious Albert Lasker Clinical Medical Research Award, "I waited for 25 hours—and joy unbounding! A beautiful diakinesis, superb chromatids…Now a definite future existed for human IVF."

Retrieving tissue from a woman's ovaries required minimal surgery. To this end, Edwards partnered with Patrick Steptoe,



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an obstetrician and gynecologist who was an expert in the technique of laparoscopy. They collaborated for ~20 years, until Steptoe's death in 1988. Against seemingly insurmountable odds—little human material available for research, a modest laboratory, no government funding, as well as strong disapproval from colleagues and the public—Edwards worked passionately and methodically over decades to achieve the dream he had as a graduate student. His publications during the 1960s and 70s lay out the blueprint of his plan for bringing human IVF to fruition. (He also described prenatal genetic diagnosis, stem cells, and cloning.) The initial attempts were frustrating, as egg cells that were matured and fertilized in vitro failed to initiate pregnancy when transferred back into the uterus. Edwards concluded that for IVF to work, eggs that matured during the natural menstrual cycle had to be collected from patients. This key insight, among others, led to the birth of Louise Brown, the first test-tube baby, on 26 July 1978.

Although Edwards and a lawyer, David Sharpe, outlined in a 1971 *Nature* article the difficult social and ethical issues that human embryo research entailed, major arguments in the press and criticism from colleagues formed a constant backdrop to his work with Steptoe. As Edwards wrote in the 2001 article, "Ethicists decried us, forecasting abnormal babies, misleading the infertile and misrepresenting our work as really acquiring human embryos for research." On one particular day, Edwards issued eight libel actions in the High Court of London. "I won them all, but the work and worry restricted research for several years."

After Edwards and Steptoe achieved their goal in 1978, they were told that government funding for their work would not be forthcoming. Again, the team entered uncharted waters, but emerged years later once they garnered private support, and founded the Bourn Hall Clinic in Cambridge for training gynecologists and biologists from around the world. Where did his colossal motivation come from? One source was Edwards's passion for developmental biology. He was also deeply moved by the plight of infertile couples who ultimately made IVF possible by bravely participating in the work before there was any evidence it would succeed. As he and others learned to recapitulate fertilization and the initial steps of embryo development in vitro using animal models, he became increasingly convinced that these technologies could be translated to humans.

Despite the importance of studying human reproductive biology, proven by the work of Edwards and others, many aspects of this research remain challenging. In the United States, the Dickey-Wicker Amendment, passed every year since 1996, prohibits the use of federal funds for research that creates or destroys human embryos. Accordingly, the derivation of human stem cells from embryos, which was first reported by James Thomson in 1998, was accomplished with nonfederal funds as must be the case for all such stem cell lines derived in the United States.

Through Edwards's energy, determination, and rigorous study, IVF is now considered common medical practice. Unfortunately, societal and governmental views toward studying human development have not evolved apace. What would Edwards, one of the most provocative medical researchers and humanists in modern history, think of this situation? As he wrote in the 1971 article, "When scientists clearly foresee potential conflicts with existing rules of society arising from their work, paradoxically both human progress and scientific freedom may hang on their activism in arenas generally regarded as social or political."

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[1]Obstetrics, Gynecology and Reproductive Sciences, [2]Human Embryonic Stem Cell Program, University of California San Francisco, CA 94143, USA. [3]American Society for Reproductive Medicine, Birmingham, AL 35216. E-mail: sfisher@cgl.ucsf.edu; giudice@obgyn.ucsf.edu