# NUCLEAR ENERGY IMPACTS ON HEALTH

**Michael H. McGovern**
*Senior Analyst, Center for Verification Research, USA*

**Jaya Tiwari**
*Phd Candidate, Old Dominion University, USA*

**Keywords:** Nuclear Energy, health effects, radiation, nuclear fuel cycle, nuclear accidents, Three Mile Island, Chernobyl, dose-response, radiation standards, ICRP, NCRP…

## Contents





## Summary

The first section of this article addresses the nature of health risks associated with the production of nuclear energy. While positive impacts are acknowledged, the focus is on the landscape of risks that give rise to detrimental impacts unique to this energy source, since these are a considerable source of controversy. In the second section, the article explores trends and issues that are likely to bring more attention to the issue of nuclear energy impacts on health. These trends include the growing use of nuclear energy in the developing world; the debate over nuclear energy's potential role in limiting annual green house gas emissions; and a growing body of research on the health effects of low levels of ionizing radiation.

In the third section, the stages of the nuclear fuel cycle and the sources of potential impacts at each stage on both worker and public health are examined. The impacts on health of accidents in reactors and other fuel cycle facilities are also explored. The fourth section covers the national and international regimes in place to limit nuclear energy impacts on health, focusing on institutions. The section also includes a discussion of recent debates over the validity of the linear non-threshold dose response model, which holds that health effects, at very low levels of exposure to radiation, are proportional to received dose. Rejection of this model, which has been used by most international and national institutions charged with the development of standards, could have considerable implications for health regulation throughout the fuel cycle. The final section provides the authors' concluding remarks about priority areas for research.

## I. Nuclear Energy and Health: Categories of Risk

An exploration of nuclear energy impacts on health is complicated by several factors. First, scientific understanding of the translation of health risks into effects is not complete. A key example of this problem is the current debate over the validity of the linear non-threshold dose response model, which for years has supported the development of radiation standards established to protect nuclear industry workers and the public. Second, compared to other forms of energy, nuclear energy is surrounded by a highly complex web of political, economic, environmental, safety and other issues. An examination of impacts on health cannot ignore the context formed by, and values linked to, many of the above factors. Third, discussions of health impacts can be quickly polemicized. Epidemiological studies that indicate one result or another may become irrefutable evidence in the minds of advocates on either side of the nuclear energy debate. In this debate, it is difficult not to be reminded of the famous statement "There are lies, damned lies, and statistics." One epidemiologist recently remarked "What leads two groups of epidemiologists to attach different meanings or give different emphasis to essentially the same data is a puzzle that is likely to remain with us for as long as subjectivity plays a role in epidemiology."[1]

For these and other reasons, this discussion makes no attempt to quantify nuclear energy impacts on health, nor does it pass judgment on the merits of this energy source. Rather, the article identifies *the nature* of health hazards, risks and impacts arising from nuclear energy; describes these at each stage in the process of nuclear energy production; sketches the landscape of contemporary issues and concerns, including recent controversies; addresses the regimes in place to guard against detrimental impacts; and makes recommendations for further research. The article concludes with the authors' thoughts on holistic approaches to consideration of nuclear energy impacts on health.

It should be no surprise that nuclear energy has both positive and negative impacts on health. Broadly speaking, on the positive side, nuclear energy, like other energy sources, provides electricity that permits societies to maintain or develop modern economies that realize positive health benefits, including higher living standards and improved health care access. On the negative side, nuclear energy, like other sources, relies on materials and operations that pose health risks to both industry workers and members of the public who reside within the vicinity of facilities. These risks may manifest themselves in populations as deleterious health effects.

There is little debate over the positive health impacts of nuclear energy or other energy sources for that matter. It is the presence and magnitude of *negative* health impacts that have been a major battleground in the long-standing war among advocates and opponents of nuclear energy. For the purposes of this discussion, a health "impact" can be considered as the manifestation in populations of health effects arising from risks posed by hazards. Hazards and risks particular to nuclear energy are discussed in Section 3 below. A health impact does not by force arise from the mere presence of a hazard. The magnitude of a hazard and potential exposure pathways from the hazard to humans determine the significance of health risks, and it is in the absence of fully adequate risk mitigating measures, which may not always be available, that health impacts occur.

The operations and materials normally associated with the production of nuclear energy pose numerous health risks, which can be broadly categorized as radiological and non-radiological in nature.

- Radiological health risks arise from the presence at each stage in the nuclear fuel cycle (discussed below) of materials that emit radiation. Of concern are materials that emit gamma rays, alpha particles, beta particles and neutrons. Gamma radiation, alpha particles and beta particles are forms of ionizing radiation energetic enough to break chemical bonds in living cells, which can be very detrimental to human health. Neutrons, while not directly ionizing, are very penetrating and can impart considerable energy to human tissue. When ingested or inhaled, radioactive materials pose particularly significant risks, since they more readily cause tissue and other damage from within the body. Depending on factors such as total dose, dose rate, whole body vs. partial body irradiation, internal vs. external exposure, age at exposure, and the nature of radiation in question, the health effects that may arise from radiation exposure include various forms of radiation sickness, thyroid disease, numerous cancers, long-term health problems, genetic effects that can manifest themselves in future generations, and death.[2,3]
- Throughout the nuclear fuel cycle, many activities require the use of heavy machinery and equipment, hazardous chemicals, and large, complex facilities. The non-radiological health risks posed by such activities are similar to those one might expect to find associated with any large-scale industrial endeavor. For example, just as any industrial endeavor, fuel cycle activities have given rise to physical injury from faulty machinery, the careless operation of equipment, fires and explosions. Physical injury, illness and cancer are effects that may arise from inadvertent exposure to chemicals and materials used in fuel cycle activities. Uranium-238, for example, which is ubiquitous in the fuel cycle, is toxic and has been shown to impair kidney function in humans when ingested.[4]

In addition to the risks associated with normal operations, there are also radiological and non-radiological health risks associated with nuclear accidents and with the misuse or unauthorized use of nuclear materials and facilities. As demonstrated in 1986 at Chernobyl, nuclear plant accidents can result in the release and dispersion into the environment of large quantities of radioactive materials hazardous to human health. High levels of radiation exposure to workers and members of the public can ensue, causing acute radiation effects and death. Beyond the health effects arising from radiation exposure, physical injury to workers can result from an accident, and an accident may create panic in populations and lead to physical injuries. Perhaps the greatest possible health impact that could arise from nuclear energy is the clandestine development and use of nuclear weapons by a nation using materials that have been diverted from civilian nuclear energy facilities.

A final set of impacts on health that may arise from nuclear energy is psychological in nature, relating to mental health. For a number of reasons, it has been argued that both normal operations and accidents pose psychological risks to workers and members of the public. Believers in the notion of psychological impacts from nuclear energy argue that psychological risks arise because 1) radiation is invisible, tasteless, odorless and

generally intangible and 2) it is not uncommon for the potential consequences of nuclear energy accidents to be equated with the effects of nuclear weapons.[5] According to this perspective, public fear of being unable to detect and avoid radiation and the fear of Hiroshima-like consequences of nuclear industry accidents may lead to feelings of anxiety and dread among members of communities near nuclear installations.

Beyond the psychological risks associated with normal operations, it has been argued that in the event of actual nuclear accidents, psychological impacts can be particularly pronounced. In fact, it is generally accepted that the Chernobyl accident had significant psychological impacts on affected populations, even on those populations with relatively low exposures to radiation. These impacts arose, according to some analysts, because the accident was followed with inadequate or conflicting information and it ultimately disturbed the life patterns of many individuals.[6]

## 2. Why Does This Issue Matter: Important Trends and Issues

There are several reasons why at the end of the 20th Century the health impacts of nuclear energy warrant heightened attention.

First, nuclear energy is a major source of the world's energy, representing in 1997 approximately 17% of all electricity generation and 7% of all energy production.[7] According to the International Atomic Energy Agency (IAEA), a total of 437 operating commercial reactors in 32 countries had a capacity of some 350 Gigawatts of energy.[8] In addition to reactors, thousands of supporting facilities, from uranium mills to spent fuel reprocessing plants to waste disposal facilities, facilitated nuclear energy production. Through the employment provided by the nuclear industry and the energy it generated, nuclear energy touched the lives of millions of industry workers and members of the public around the world. Nuclear energy has been an important energy source for a considerable period of time and a great body of data relevant to its health impacts has accumulated. A concerted effort to analyze this data and improve understanding of the health impacts associated with past operation can inform future decisionmaking about nuclear energy.

Second, there is a considerable gap in the developing world between energy needs and available supply. This gap may increase as a consequence of continued population growth. According to the United Nations, populations in the developing world will increase by 2 billion people over the next 25 years, growing from 4.7 to 6.6 billion, rising to 85% of the global population.[9] During that period, developing country energy requirements are expected to grow dramatically to meet the needs of larger populations and to improve standards of living. The OECD's International Energy Agency (IEA) estimates that by 2020 developing countries' energy demand will nearly double and their share will grow from around 35% to 45% of global energy demand.[10] Nuclear energy is expected to play an increasingly important role in some nations of the developing world. In China, for example, official government plans call for an increase in nuclear capacity from 2 Gigawatts to 40 - 50 Gigawatts by the year 2020.[11] In India, official plans call for an increase from the current level of 2 Gigawatts up to 20 Gigawatts by 2020.[12] While OECD estimates are lower than the official country estimates (20 Gigawatts and 4 Gigawatts, respectively), significant growth in nuclear

power capacity is expected. Improved understanding of nuclear energy impacts on health will be of considerable benefit to China, Indian and other developing nations as they move forward into the 21st Century with nuclear power as an increasingly important energy source.

Third, a considerable number of nuclear reactors in Western nations, particularly the United States, are approaching the end of their planned operating life. Decisions need to be made regarding whether to replace old reactors with new nuclear reactors, substitute reactors with fossil fuel plants and/or other energy sources, or extend the operating licenses of reactors and effectively postpone hard decisions about replacement.

Projections from several respectable sources, including the NEA, IAEA, and WEC, indicate that nuclear energy will continue to increase in global importance through the year 2010.[13] Beyond 2010, however, national policies, particularly in the United States, regarding reactor retirement and new construction, along with energy market competition, will determine the overall growth rate of this energy source. A more thorough understanding of nuclear energy impacts on health could inform the development of national policies relevant to nuclear energy.

Fourth, evidence continued to accumulate indicating that emissions of carbon dioxide from the burning of fossil fuels were linked to global warming. Growing concern over climate change renewed debate over the viability of nuclear energy as an energy source in the long term. In December 1997, at the Conference of Parties to the Framework Convention on Climate Change, held in Kyoto Japan, countries reached agreement on national reductions of carbon dioxide emissions.

Pursuant to the goals elaborated at Kyoto, many have argued that nuclear power, while an energy source with its own unique problems, can contribute to lower carbon dioxide emissions since it is essentially a carbon-free source.[14] In light of the potential climate impacts of fossil fuels and the promise of nuclear energy to reduce carbon emissions, a more thorough understanding of nuclear energy impacts on health is important to facilitate informed judgments about the appropriate roles for these energy sources in the future.

Fifth, currently held views of the health risks associated with low-level ionizing radiation, a hazard unique to nuclear energy, are under scrutiny. In particular, recent work has given rise to renewed debates over the validity of the linear non-threshold dose response model, which holds that the relationship between health effects and radiation dose at high levels of exposure can be extrapolated downward in a linear fashion to predict health effects from low levels of radiation exposure.

Current radiation protection standards, which are based on linear non-threshold assumptions, could be reconsidered if the linear non-threshold dose response model falls out of favor. It has been argued that revised standards could have considerable implications for health regulation throughout the fuel cycle and a tangible impact on the economics of nuclear energy through less stringent and costly practices associated with normal operations such as waste disposal and facility decommissioning.[15]

-
-
-



**Bibliography**

Alan Martin and Samuel Harbison (1996) *An Introduction to Radiation Protection*, 230 pp. London: Chapman and Hall Medical.

American Medical Association, Council on Scientific Affairs, "Medical Perspective on Nuclear Power," *The Journal of the American Medical Association*, November 17, 1989, v262 n19 p2724(6)

Andrew S. Skolnick, "Downwinders Angry about Medical Screening Lack," *The Journal of the American Medical Association*, August 5, 1998, vol. 280, no. 5.

Charles W. Henson, "Chernobyl Poisons Ukraine 12 Years After Explosion," *Cancer Weekly Plus*, May 4, 1998

Committee on Health Effects of Exposure to Low Levels of Ionizing Radiations (BEIR VII), National Research Council (1998) *Health Effects of Exposure to Low Levels of Ionizing Radiations: Time for Reassessment?*, XXpp. Washington DC: National Academy Press.

Committee on Radiation Protection and Public Health, OECD Nuclear Energy Agency, *Developments in Radiation Health Science and Their Impact on Radiation Protection*, OECD NEA, 1998

Eli Lake, "Linear Dose-Response Model at Issue as Scientists Reexamine Data," *Risk Policy Report*, January 24, 1997

Furio Pacini and Aldo Pinchera, "Prevelence of Thyroid Autoantibodies in Children and Adolescents from Belarus Exposed to Chernobyl Radioactive fallout," *The Lancet*, Sept. 5, 1998, vol. 352, no. 9130

Geoffrey H. Stevens, Head, Nuclear Development Division, "Summary of Remarks at Global'97," OECD Nuclear Energy Agency

Hans Blix, "Nuclear Energy in the 21st Century," Address of IAEA Director General at Joint IAEA/CNNC Seminar on 21st Century Nuclear Energy Development in China, 23 May 1997

IAEA, "Nuclear Power Status Around the World," *IAEA Bulletin*, April 1998

International Commission on Radiological Protection, *Recommendations of the International Commission on Radiological Protection (Publication No. 60)*. Elmsford, New York: Pergamon Press.

International Energy Agency (1998) *World Energy Outlook*, Paris: OECD.

Joby Warrick, "Atomic Split: Data Recharge Debate on Low-Level Radiation Risk," The *Washington Post*, April 14, 1997, p. A3

Joby Warrick, "Study Links Three Mile Island Radiation Releases to Higher Cancer Rates," *The Washington Post*, February 24, 1997

I. K. Ivanov "Thyroid Cancer Among 'Liquidators' of the Chernobyl Accident" *British Journal of Radiology*, vol. 70, 1997.

Kate Probst and Michael McGovern (1998) *Long-Term Stewardship: The Challenge Ahead*, Washington, D.C.: Resources for the Future

Maureen C. Hatch et al., "Cancer rates after the Three Mile Island nuclear accident and proximity of residence to the plant," *The American Journal of Public Health*, June 1991 v81 n6 p719(6).

Myron Pollycove, "The Rise and Fall of the Linear no-Threshold Theory of Radiation Carcinogenesis," *Nuclear News*, v.40, June 1997, pp.34-37

OECD Nuclear Energy Agency (1993) *The Safety of the Nuclear Fuel Cycle*, 244 pp. Paris: OECD.

OECD Nuclear Energy Agency (1998) *Nuclear Energy Data*, 45 pp. Paris: OECD.

OECD Nuclear Energy Agency, "Chernobyl: Ten Years on Radiological and Health Impact," An Assessment by the NEA Committee on Radiation Protection and Public Health, Nov. 1995, OECD NUCLEAR ENERGY AGENCY

OECD Nuclear Energy Agency, *Work Management in the Nuclear Power Industry*, 1997, 164 pp. Paris: OECD

OECD Nuclear Energy Agency/International Atomic Energy Agency (1997) Occupational Exposures at Nuclear Power Plants (1969-1995): Information System on Occupational Exposure, Fifth Annual Report, pp.163,Paris:OECD.William Schull (1995), Effects of Atomic Radiation, pp. 397. New York: Wiley-Liss

P.D. Wilson et al (1996) *The Nuclear Fuel Cycle: From Ore to Waste*, 323 pp. Oxford: Oxford University Press

Raymond Murray (1994) *Understanding Radioactive Waste*, pp. 212. Columbus, Ohio: Battelle Press.

Regional Office for Europe, World Health Organization (1994) *Nuclear Power and Health: The Implications for Health of Nuclear Power Production*, 145pp. Copenhagen: WHO.

RH Nussbaum, "The Linear no-Threshold Dose-Effect Relation: Is It Relevant to Radiation Protection Regulation?," *Med Phys*, March 1998, pp. 291-299

Stefan Wagstyl, "Enduring Power of Survival," *Financial Times*, Thursday April 16, 1998

William H. Hallenbeck (1994) *Radiation Protection*, pp. 269, Boca Raton, USA: Lewis Publishers.

William Nordhaus, *The Swedish Nuclear Dilemma*, Resources for the Future, 1997

Zamora,M.L., Tracy, B.L., Zielinski, J.M., Meyerhof, D.P. and Moss, M.A.: "Chronic Ingestion of Uranium in Drinking Water: A Study of Kidney Bioeffects in Humans," *Toxicologcal Sciences* Vol.43, No.1, (May 1998), p. 68-77

**Biographical Sketches**

**Michael McGovern** is a Senior Analyst with Analytical Systems Engineering Corporation (ASEC) and based at the Center for Verification Research in Springfield, Virginia (USA). Mr. McGovern works on nuclear and other arms control issues, with a focus on technologies required for treaty and agreement implementation. Prior to joining ASEC, Mr. McGovern worked at Resources for the Future (RFF), an environmental policy research organization, where he examined and wrote about the environmental cleanup of the U.S. Department of Energy's nuclear weapons complex. Mr. McGovern's related experiences include employment at the Twentieth Century Fund, a public policy research organization based in New York, where he worked on environmental issues; employment at the American Embassy in Paris, where he tracked and reported on developments in the French civilian nuclear energy program; and teaching positions at Princeton University and the University of Massachusetts at Amherst, where he taught about nuclear weapons and nuclear energy issues. Mr. McGovern has an MPA, International Affairs, from Princeton University's Woodrow Wilson School, and an MS, Physics, from the University of Massachusetts at Amherst.

**Jaya Tiwari** is a Ph.d. candidate at Old Dominion University in Norfolk, Virginia. She is completing her doctorate in International Studies with a focus on nuclear and security issues. Ms. Tiwari has worked at the Center for Defense Information (CDI), a defense policy research organization based in Washington DC, where she examined and wrote about nuclear weapons issues, including the nuclear weapon programs of India and Pakistan and the nuclear weapons accidents of Britain and the United States. She has also worked at the US National Aeronautic and Space Administration (NASA), on the research program "Global Challenges and Mission to Planet Earth." Ms. Tiwari has presented a number of papers on nuclear and national security issues in different national and international conferences. She has a master's degree in International Studies from Old Dominion University, and a master's degree in Political

Science from Banaras Hindu University, Varanasi (India), with concentrations in public administration and international law.

## ENDNOTES

[1] Joby Warrick, "Study Links Three Mile Island Radiation Releases to Higher Cancer Rates," *The Washington Post*, February 24, 1997
[2] William H. Hallenbeck, *Radiation Protection*, Lewis Publishers, 1994, p. 10
[3] American Medical Association, Council on Scientific Affairs, "Medical Perspective on Nuclear Power," *The Journal of the American Medical Association*, November 17, 1989, v262 n19 p2724(6)
[4] US Agency for Toxic Substances and Disease Registry, *Public Health Statement on Uranium*, 1990, and Zamora,M.L., Tracy, B.L., Zielinski, J.M., Meyerhof, D.P. and Moss, M.A.: "Chronic Ingestion of Uranium in Drinking Water: A Study of Kidney Bioeffects in Humans," *Toxicologcal Sciences* Vol.43, No.1, (May 1998), p. 68-77
[5] World Health Organization, *Nuclear Power and Health: The Implications for Health of Nuclear Power Production*, WHO Regional Publications, European Series, No. 51, p. 107
[6] Ibid
[7] Geoffrey H. Steven, Head, Nuclear Development Division, OECD Nuclear Energy Agency. "Summary of Remarks at Global'97," and Hans Blix, Director General, International Atomic Energy Agency, "Nuclear Energy in the 21st Century," Address at Joint IAEA/CNNC Seminar on 21st Century Nuclear Energy Development in China.
[8] "Nuclear Power Status Around the World," *AIEA Bulletin*, December 1998, p.54
[9] United Nations, *World Population Prospects*, 1998 Revised
[10] OECD International Energy Agency, Key Statistics, URL: www.iea.org/stats/files/keystats/p_0702.htm
[11] OECD International Energy Agency, *World Energy Outlook*, 1998 pp. 289-290
[12] R Chidambaram, Chairman of India's Atomic Energy Commission, "India's Nuclear Program: Essentially Peaceful," *India Perspectives*, August/September and OECD International Energy Agency, *World Energy Outlook*, 1998 pp 337-338
[13] OECD Nuclear Energy Agency, *Nuclear Energy Data*, 1998, pp. 10 – 12; Noboru Oi and Lothar Wedekind, "L'Evolution des Perspectives Mondiales: Les Tendances du Cycle du Combustible Nucleaire Au-Dela de L'An 2000," AIEA Bulletin, March 1998, p. 8
[14] OECD Nuclear Energy Agency, "Trends in Nuclear Power," 1997 *Annual Report*, OECD Nuclear Energy Agency, p.6
[15] See, for example, Joby Warrick, "Atomic Split: Data Recharge Debate on Low-Level Radiation Risk," *Washington Post*, p. A3, 4/14/97 and ????