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A review of *Analysis of Cancer Risks in Populations near Nuclear Facilities: Phase I*

BY ARJUN MAKHIJANI, PH.D.

In 2012 the National Research Council of the National Academies released *Analysis of Cancer Risks in Populations near Nuclear Facilities: Phase I*.[1] The study is meant to examine the feasibility of, and identify scientific approaches to, estimating cancer risks to people living near nuclear facilities, including nuclear power reactors. This report is a thoughtful and substantive contribution to the literature on cancer risks that people may face if they live near nuclear facilities. The initial findings and recommendations from this first scoping phase of the analysis are discussed below, followed by IEER's analysis.

Data issues: Multiple challenges make it difficult to conduct accurate epidemiologic studies of cancer risks in populations near nuclear facilities. Most data on cancer deaths are provided at the county level. Because individual states are responsible for tracking the data on cancer and cancer deaths, there are inconsistencies in what information is available and the quality of that information. This makes it difficult to compare the data. Because the release of radioactivity is not limited to particular geographic boundaries, the ability to analyze data on multiple levels is necessary to accurately consider the role a nuclear facility may play in cancer development and frequency. In addition, there is inconsistent availability and quality of data on the effluent releases from nuclear facilities. And these releases have changed in amount and composition over time, further complicating the analysis. The lack of historical measurements of carbon-14 releases is a particular problem.

Similarly there is a lack of access to accurate data regarding the many other factors that must be analyzed to determine what role, if any, a nuclear facility played in the development of a cancer. Such factors include lifestyle risks such as smoking and access to health care, and also include issues of background radiation and medical radiation exposure, as well as unknown toxic exposure and other unknown lifestyle risks. There is also the issue of population mobility, which is particularly problematic in this type of analysis because cancer can take years before it is diagnosed, and may not be discovered while the patient is still living near a nuclear facility.

Courtesy: ©PPL Susquehanna

Susquehanna Steam Electric Station, Units 1 and 2. Taken on November 20, 2007. The nuclear power plant is located near Salem Township, Luzerne Co., PA. More information on the NRC facility at www.nrc.gov/info-finder/reactor/susq1.html and at www.nrc.gov/info-finder/reactor/susq2.html.

Approaches to the study: There is no single approach to the analysis, rather there are many different ways to assess cancer

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On life near two nuclear power plants in Illinois

An interview with Cindy and Joe Sauer

BY ARJUN MAKHIJANI, PH.D.

Introduction: There are two reactors each at the Braidwood and Dresden nuclear power plants in Illinois. Braidwood has two Westinghouse pressurized water reactors that were commissioned in 1988 with a total combined power rating of 2,330 megawatts. Dresden has three General Electric boiling water reactors of a design similar to the stricken reactors at Fukushima Daiichi in Japan. Unit one was a small unit of 210 megawatts commissioned in 1960. It was shut in 1978 and decommissioned. Units 2 and 3 are rated at 867 megawatts each and are still operational; they were commissioned in 1970 and 1971 respectively. They have had their licenses extended for 20 years beyond the initial 40 years. The current schedule for closure is December 2029 for Unit 2 and January 2031 for Unit 3. The Braidwood and Dresden nuclear power plants have leaked tritium in the form of radioactive water to the environment. Cindy and Joe Sauer lived in the area of these reactors from 1998-2004. Subsequently to their finding of tritium leaks and contamination and that many children in the area had

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INSIDE

EDITOR'S NOTE

This issue of *Science for Democratic Action* is focused on the health effects of radiation, and in particular the known and unknown health effects associated with the nuclear power industry. The work referenced in this issue covers a wide range of topics, from low-level waste regulations to epidemiologic studies, to the connections with nuclear weapons, and citizen science. Much of our work in these areas, and in particular on the human health impacts of radiation, stems from our Healthy from the Start project and the extensive report *Science for the Vulnerable*. For more information and materials visit www.ieer.org/projects/healthy-from-the-start.

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risks in the populations around nuclear facilities, each with their own benefits and drawbacks. The study examines risk-projection models, ecologic studies, cohort studies, and case-control studies.

Determining radiation dose: Determining a rough estimate of radiation dose as a function of distance and direction from nuclear facilities can be obtained if the data on effluent releases, direct exposures, and meteorology data are available (see sidebar on page 3).

The following are the recommendations of the report authors, as presented for consideration to the Nuclear Regulatory Commission (NRC):

1. Two types of studies should be used to analyze the cancer risks in populations near nuclear facilities. These studies are complementary by first providing a broad look at cancer incidence and mortality over the operational lives of the facilities, as well as providing a more detailed examination of these cancers in relation to early life exposure. It will be up to the NRC to determine if they pursue these two studies or pursue other studies.

- An ecologic study that looks at the multiple cancer types in communities within 30-miles (50-kilometers) of nuclear facilities. This would incorporate both the most potentially exposed as well as those not likely exposed for comparison. The authors also recommend an approach for organ dose estimation.
- A case-control study of cancers in children in these communities that looks at childhood cancers in relation to the maternal residential proximity at the time the child was born. Again this would be within a 30-mile (50-kilometer) radius of the facility.

2. Carry out a pilot study to assess the feasibility of the studies recommended above, and to estimate what these studies will cost and how much time they might take. Six nuclear facilities would be examined in this pilot phase: Dresden, Millstone, Oyster Creek, Haddam Neck, Big Rock Point, San Onofre, and Nuclear Fuel Services. The first five in this list are reactor sites, while the last is a nuclear fuel processing site. Haddam Neck and Big Rock Point were shut in the 1990s.

3. Stakeholder engagement should be an essential component of these studies and should happen prior to data collection and analysis.

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IEER's analysis:

Overall, this is a thoughtful and careful report regarding the difficulties and complexities of conducting successful epidemiologic studies to detect whether there is excess cancer in the neighborhood of commercial nuclear facilities. It has compiled the available data and noted the limitations of the data. Given the vast differences in risk of various types of adverse outcomes between those exposed in utero and in early infancy, the feasibility study should focus on the case control study for children and not also attempt the ecologic studies at the same time.

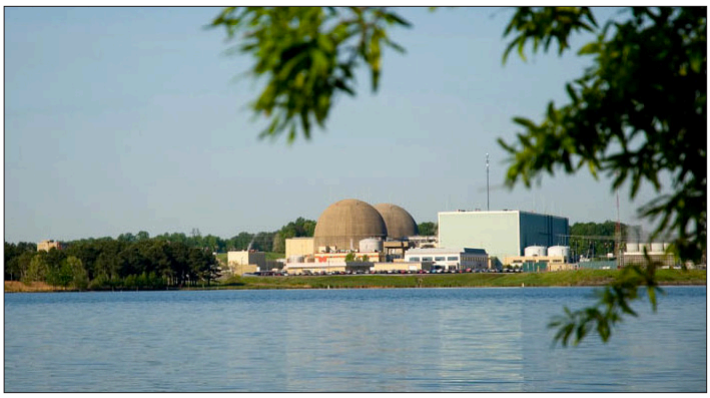
IEER's view is that the ecologic study is not worth doing, since the confounding factors are many: using distance as a surrogate for dose, notably for those who are not children; the serious data gaps; the movement of populations in and out of the area, etc., among other problems. Such problems were noted in the report and, in our view, cannot be reliably overcome. If an ecologic study is done, it should be done only after the case control study is completed.

Even the case control study, which we recommend be done, would face many critical data gaps, particularly in light of non-cancer effects as well as cancer risks as a result of in utero and/or early childhood exposure. The adverse health outcomes that should be evaluated include: cancer incidence for various cancers, including leukemias of various types, and brain and nervous system cancers; cancer deaths; early failed pregnancies; malformations as affected by early embryo/fetus exposure (first 14 weeks); and immune system function as affected by fetal exposure at the time of bone and bone marrow formation. The reliable determination of strontium-90 exposure (in addition to tritium and carbon-14 exposures) is important in this context.

Radiation Dose and Exposure

IEER has a number of related materials on the web discussing the many issues related to radiation dose and exposure:

- Table of tritium releases, both gaseous and effluent, from nuclear facilities from 2004 and 2005: http://ieer.org/resource/tritium/tritium-releases-to-air-and-water-from-nuclear-power-plants-tables-of-data-from-2004-and-2005/.
- IEER's report *Science for the Vulnerable*, published in 2006, discusses the issues with use of "Reference Man". Particularly the report focuses on the disproportionate risks faced by children exposed to radiation: http://ieer.org/resource/reports/science-vulnerable-setting-radiation/.
- *Science for Democratic Action*, volume 16 number 1 includes features "Radioactive Rivers and Rain: Routine Releases of Tritiated Water from Nuclear Power Plants" and "Retiring Reference Man: The Use of Reference Man in Radiation Protection with Recommendations for Change": http://ieer.org/article/science-for-democratic-action/volume-16-number-1/.
- *Science for Democratic Action*, volume 14 number 4, includes features "Healthy from the Start: Building a Better Basis for Environmental Health Standards – Starting with Radiation" and "Health Risks of Tritium: The Case for Strengthened Standard": http://ieer.org/article/science-for-democratic-action/volume-14-number-4/.



Courtesy: ©Dominion Energy

North Anna Power Station, Units 1 and 2. Photo taken 2007. The nuclear power plant is located near Louisa, VA. More information on the NRC facility page link at www.nrc.gov/info-finder/reactor/na1.html and at www.nrc.gov/info-finder/reactor/na2.html.

1. **Tritium releases to the atmosphere:** There is no discussion in the report about tritium releases to the atmosphere, even though this was pointed out to the panel in IEER's April 26, 2010 presentation (http://ieer.org/resource/testimony/perspectives-on-the-nas-studying-cancer-risk-in-populations-living-near-nuclear-power-facilities/). Light water reactors routinely release tritium to the atmosphere in the form of tritiated water vapor. Tritiated water comes down mixed with ordinary rainwater, contaminating land, locally grown produce, and groundwater. This lack of discussion is a serious omission, especially in view of the fact that private water wells are not covered or monitored under the drinking water act. The Nuclear Regulatory Commission does not require or recommend that licensees monitor drinking water from private wells, even if the well owners so desire. Under certain circumstances, the concentration of tritium in rainwater can far exceed the drinking water limit. There are multiple pathways of exposure to tritiated rainwater including absorption through the skin, various food pathways that include exposure to organically bound tritium, irrigation with contaminated well water, consumption of contaminated well water for drinking and cooking, and inhalation of contaminated water.

2. **Tritium discharges to surface waters:** Sampling for tritium is episodic rather than continuous. It is critical to know that measurements of concentrations in primary water have been made and to validate the surface water sampling results with primary water sampling data, if they exist. If they do not exist, it will be important to make estimates by independent methods, such as knowledge of reactor operation and primary water discharge protocols (see sidebar on page 4).

3. **Tritium minimum detectable amounts (MDAs):** The NRC required MDAs (also referred to as the lower limit of detec-

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tion, or LLD) for tritium are often on the order of 2,000 pCi/liter. This is far too high. An effort should be made to determine the concentration levels by estimating it from knowledge of amounts of tritium created in the reactor and discharged.

4. **Strontium-90:** IEER recognizes that official data indicate that strontium-90 emissions and discharges during routine operation would be low. However, as the report recognizes, early data have gaps and older reactors with problematic fuel rods could have resulted in strontium-90 discharges to surface waters when primary water was discharged, or possibly even to the atmosphere. In utero exposure as well exposure during infancy to strontium-90 could compromise immune system stem-cell development, creating greater vulnerability to cancer as well as a host of other diseases. (Editor's note: Analysis of tritium, strontium-90, and other matters with specific reference to women and children can be found in the IEER report *Science for the Vulnerable*[2].)

Even once the data gaps are addressed, there remain, in our opinion, areas of analysis that are missing from the report and should be included in the next steps. These issues include:

A. **Exposure to tritium during the first eight weeks:** The proposed case-control study is focused on health outcomes of children whose mothers lived near nuclear plants during pregnancy. It is therefore necessary to be able to calculate doses to the embryo/fetus during all stages of the pregnancy. ICRP 88 proposes that the doses during the embryonic stage – the first eight weeks – should be "taken to be the same as the dose to the uterus wall."[3] While this may be appropriate for photon and high energy beta emitters, it is not suitable for the low energy beta of tritium or for alpha-emitting radionuclides. The recommendation that the case-control study focus on the area where the mother lived during pregnancy is important. But for the study to be valid in regard to vulnerabilities acquired during the first eight weeks of pregnancy when most of the organs are formed, a better method of estimating doses during this period will be needed, especially for tritium. The validity of the method for carbon-14 and strontium-90 should be examined.

B. In view of the considerations in item A just above, **it would be better to focus the study on children at the time of conception** rather than at the time of birth of the children in the case-control study.

C. **Exposure to multiple nuclear facilities:** The study focuses on getting dose estimates from single facilities. But in certain cases, such as that of the Braidwood plant, many of the affected people are also affected by the Dresden plant. It will be important to consider exposures to the affected population from all nuclear fuel cycle facilities, including other nuclear power plants, of course.

D. **Exposure to carcinogens from other facilities:** The presence of chemical facilities or fields where pesticides are sprayed, especially by air, should be noted in the study. Petroleum refineries, for instance, may emit carcinogens. This may be a confounding factor in some situations. At the very least, such potential confounding factors should be noted.

E. **Exposure geography:** Defining the exposed populations will be complex. We have already pointed out the issue of tritiated rainfall, which will depend on rainfall patterns as well as air dispersion. The location of public drinking water systems downstream of the water discharge points is also important. For instance, there is a public drinking water system downstream of the Braidwood and Dresden plants in Illinois. The water quality data for such public drinking water systems should be examined to determine whether the women who were pregnant in these areas should be included in the studies. It is unclear whether babies born to mothers who lived within a 30-mile (50-kilometer) radius, which is proposed in the report, is the most appropriate geographic definition for these studies. One early step might be to examine weather data and water consumption patterns and choose the area for study that way.

In the case of Dresden, the combined exposures from Dresden and Braidwood should be evaluated and the exposed populations should be selected with both these facilities in mind. In this regard, IEER strongly recommends that the data and analysis of childhood cancer prepared by and presented to the committee by Dr. Joseph Sauer be explicitly taken into account and included in the case control study for these facilities.

Editor's note: For additional information on terms and measurements related to radiation doses to organs, see the IEER factsheet published in March 2011, just after the Fuskushima Daiichi disaster began. You can access that factsheet on the web at http://ieer.org/resource/factsheets/radiation-and-human-health/.

What is primary water?

Primary cooling water is the water that removes the heat generated by fission reactions in the fuel present in the reactor vessel. In a pressurized water reactor (PWR) the primary water is used to heat a secondary water loop which produces the steam for electricity generation – the device is known as a steam generator. The primary water in a BWR is heated to boiling from the fission process and the steam is used directly to drive the turbine. The tritium releases from a BWR are largely in the form of tritiated water vapor. In general, more tritium is produced in PWRs in reactions with boron, which is added to PWR primary water as a means of controlling the chain reaction.

ENDNOTES

1. http://www.nap.edu/catalog.php?record_id=13388

2. Arjun Makhijani, Brice Smith, and Mike Thorne, *Science for the Vulnerable: Setting Radiation and Multiple Exposure Environmental Health Standards to Protect Those Most at Risk,* Institute for Energy and Environmental Research, Takoma Park, MD, October 19, 2006, at http://ieer.org/resource/reports/science-vulnerable-setting-radiation.

3. International Commission on Radiological Protection, *Doses to the Embryo and Fetus from Intakes of Radionuclides by the Mother* (ICRP publication 88, Annals of the ICRP, 31(1/3) 2001), Corrected version, Pergamon, Oxford, May 2002, page 24.

SAUER INTERVIEW

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cancer, brain cancer, leukemia, they moved away from the area. Their daughter Sarah was diagnosed with brain cancer when she was seven. A statement from her is at the end of this interview.

Sarah Sauer

Arjun Makhijani: Tell me how you got so deeply involved in studying cancers near the Braidwood and Dresden nuclear power plants in Illinois.

Cindy and Joe Sauer: We became concerned after learning that there had been leaks at the plants and an out of court settlement made by the Illinois Attorney General's office with the nuclear power plants for violations of the safe drinking water act.

Arjun: What did you do to try to inform yourself about these nuclear power plants when you first found out about the leaks?

Cindy and Joe: We began contacting various government agencies at the local, state and federal level. Agencies such as NRC [Nuclear Regulatory Commission], EPA [Environmental Protection Agency] and health department.

Arjun: What did Sarah's doctor say was the likely cause of her cancer?

Cindy and Joe: We were told her cancer was most likely environmentally induced. One mother told me that her physician referred to the area as the Nuclear Bermuda Triangle.

Arjun: Cindy, tell me how you first came across the concept of Reference Man and what you did when you learned how it was applied in regulation.

Cindy and Joe: I came across "Reference Man" in a discussion with the NRC when I questioned them about the information I learned regarding the out of court settlement and how Exelon had to reimburse the DNR [Department of Natural Resources] for the dead wildlife that perished as a result of ingesting the contaminated release from their plant. I wanted to know what was the impact on humans considering what happened to the wildlife. It was then that I learned of Reference Man and was told very specifically that they are permissible levels and the NRC never said safe levels. I asked them if these levels were "permissible" for a 7-year-old, 40 lb little

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ILLINOIS CANCER DATA

Below is information collected by Joseph Sauer from the Illinois Department of Public Health and the Will County Health Department which provide cancer rates at the zip code level, and focuses on the Braidwood and Dresden nuclear reactors.

This information is from a longer presentation, available online, and reprinted with permission. See this interview and the full presentation on IEER's website: http://ieer.org/resource/commentary/on-life-near-two-nuclear-power-plants-in-illinois.

Methodology:

Why Braidwood and Dresden Nuclear Reactors?

- Largest and oldest of Illinois nuclear power plants
- Poor safety history
- NRC Watch List through most of 1990's
- Numerous leaks of radioactive wastes and reactor by-products
- Two leaks in excess of 3 million gallons into ground water

Data collection

- Radius of 15 miles of either Braidwood or Dresden
- Chosen to maximize population without including Joliet which had different socioeconomic makeup
- All zip codes in which any portion lies within radius

Why these timelines (1987-1996 and 1997-2006)?

- Provides a full 20 years of data
- Similar relation to respective Census years of 1990 and 2000
- One interval prior to and one after the first reported leak of 1996

TABLE 1

Braidwood and Dresden Reactors (15 mile radius)

	Age Adjusted Cases*		(1997-2006) : (1987-96)	
	1987-96	1997-2006	Relative Risk	% Change
Oral	1,153	1,302	1.13	13.0
Colorectal	6,302	6,817	1.08	8.2
Lung	8,322	8,861	1.06	6.5
Breast	6,487	7,479	1.15	15.3
Cervix	594	581	0.98	-2.2
Prostate	6,035	7,123	1.18	18.0
Urinary	3,362	4,531	1.35	34.8
Nervous	615	801	1.30	30.2
Leukemia	3,281	4,293	1.31	30.8
Other	11,335	13,747	1.21	21.3
Total**	**48,198**	**56,792**	**1.18**	**17.8**

**Cases per 1,000,000 people, normalized to 2000 population. Differences in total due to rounding.*
***Total includes breast cancer in-situ, which was not included in the breast cancer data.*

girl; I have yet to receive an answer.

Arjun: I understand that you had considerable difficulty getting the cancer data from the State of Illinois. Can you describe some of the difficulties?

Cindy and Joe: IDPH [Illinois Department of Public Health] has a cancer data set which is available to the public. It is grouped in five year intervals and the cancers are categorized into 4 age groups and 10 cancer types. The grouping of the cancer cases in these categories limits the ability to analyze the impact of the leaks on the cancer incidence. For example, thyroid cancer is lumped into the "other" category. We, therefore, asked for access to the original data set. We were told that would be a HIPAA [Health Insurance Portability and Accountability Act] violation as it would allow identification of the individual cases. This was despite the fact that we told them they could remove any personal identifying data and that I would sign a HIPAA agreement. IDPH even refused to release the data when requested by then-Senator Obama's office.

Arjun: So what did you find when you did get the data?

Cindy and Joe: I looked at the cancer incidence around the Braidwood and Dresden Nuclear Power Plants for the 10 years before the leaks began and the ten years after. After adjusting for age, the overall cancer incidence increased 9% for the state of IL and about 18% for the area near the plants. Similarly, the rate of leukemia increased twice as fast near the plants as it did in IL as a whole. Neurologic/brain cancers actually decreased in the state of IL while the rate around the plants increased 30%. For the ten years after the leaks began, a person living near the power plants was 10% more likely to develop cancer than someone living elsewhere in IL. They were 18% more likely to develop leukemia and 23% more likely to develop a neurologic or brain cancer.

Arjun: So what were your main conclusions about childhood cancers near Braidwood and Dresden compared to the rest of Illinois?

Cindy and Joe: The pediatric cancer incidence near the Braidwood and Dresden plants increased 55% in the ten-year period since the leaks began. The overall incidence in the state of IL remained stable.

Arjun: You also took a look a the Zion nuclear power plant, which has two pressurized water reactors of 1,040 megawatts each, commissioned in 1973, but which permanently closed in 1998.

Cindy and Joe: The incidence of pediatric cancer near the Zion Nuclear Power Plant peaked in 1996, the last year it was in operation. The rates steadily decreased from that time on until by 2005 the levels were similar to the rest of the state. Again, comparing the ten years before ceasing production to the ten years after showed a 9.7% decrease in pediatric cancer around the Zion Plant.

Arjun: So what did you do with your findings?

Cindy and Joe: We, initially, contacted IDPH to allow them to confirm or refute the findings. The first response was that the data was statistically insignificant. When we pressed the department for a statement

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ILLINOIS CANCER DATA, CONTINUED

TABLE 2
Illinois Statewide Cancer Data

	Age Adjusted Cases*		(1997-2006) : (1987-96)	
	1987-96	1997-2006	Relative Risk	% Change
Oral	1,113	1,100	0.99	-1.2
Colorectal	6,089	5,969	0.98	-2.0
Lung	7,162	7,484	1.04	4.5
Breast	7,174	7,178	1.00	0.1
Cervix	650	529	0.81	-18.5
Prostate	6,077	7,062	1.16	16.2
Urinary	3,189	3,789	1.19	18.8
Nervous	657	652	0.99	-0.7
Leukemia	3,130	3,624	1.16	15.8
Other	11,172	12,603	1.13	12.8
Total**	**47,293**	**51,561**	**1.09**	**9.0**

**Cases per 1,000,000 people, normalized to 2000 population. Differences in total due to rounding.*
***Total includes breast cancer in-situ, which was not included in the breast cancer data.*

Comparison of Illinois state-wide data to Dresden/Braidwood data for the two intervals studied:

Overall cancer rate
- Illinois state-wide increased 9%
- Dresden/Braidwood increased 17.8%

Leukemia cancer rate
- Illinois state-wide increased 15.8%
- Dresden/Braidwood increased 30.8%

Brain cancer rate
- Illinois state-wide decreased 0.7%
- Dresden/Braidwood increased 30.2%

saying whether the findings indicated a problem around the nuclear power plants, we were re-directed to the legal department. We attempted to get an open meeting with the epidemiologists from IDPH to discuss the findings. Their legal counsel would not allow a meeting in which the public was in attendance. We never did get a response as to their position on the data.

Next, we presented the data to the NRC. We were informed that the NRC did not study the health impact on humans. They relied solely on the state department of public health to monitor for any health effects.

We then learned that the NRC was commissioning a study to look at the health data around the nuclear power plants. It was to be performed by ORISE [Oak Ridge Institute for Science and Education]. It was going to be similar to the previous NIH [National Institute of Health] study. We discussed the problems with credibility of such a pro-nuclear institute with Chairman Jaczko. He then halted that study and opened the study up for bid and selected the NAS [National Academies of Sciences] as the most reputable independent agency to conduct the study. We were able to present the data to the full NAS Phase 1 panel. [Editor's note: Phase 1 of the study was to examine the feasibility of epidemiologic studies and to make recommendations about whether and how they should be done.] The data was very well received and the general consensus was that the Phase 2 study needed to focus on the children living near the plants with less than stellar safety records.

Arjun: Do you support the Phase 2 study one part of which is going to look at cancer risks for everyone around six nuclear facilities and also another that will look only at children? What do you hope will be the outcome of Phase 2 of the NAS study? [Editor's note: Also see IEER comments on the Phase 1 study and IEER's memorandum regarding Arjun Makhijani's meeting with NRC Chairman, Allison Macfarlane on page 9 in this issue.]

Cindy and Joe: Yes, we clearly support this study and see it as the beginning of an ongoing process that will continue to monitor the health of individuals who live in the vicinity of nuclear plants. The goal is to provide better protective layers between the public and these plants.

Arjun: It must be very difficult to discuss all these personal difficulties that Sarah and the whole family has faced publicly. What is your main goal in going through all that?

Cindy and Joe: To provide better and more protective layers between the innocent members, particularly the most vulnerable members of the public, babies, children, women, pregnant women and these plants. To make sure that the regulations and "permissible" levels are based on independent and peer-reviewed science and truly protecting the health of people, especially the most vulnerable members of the public.

Arjun: If you are comfortable doing it, please tell us how Sarah has coped with her many challenges and what she is doing today.

Cindy and Joe: Sarah faces uphill battles every day. We try to assist her and provide her with as many opportunities to succeed and feel as though she is a contributing member of society. We have connected her with many wonderful individuals who have allowed her to volunteer and work under the guidance of very caring individuals. She has always loved animals and wanted to be a vet but that is not an option. She wanted to also work as a zoo keeper but does not have the physical abilities to do so. We have encouraged her to take her love for animals and combine it with her love for working with preschool children. Sarah has an interest in photography and has recently put together a children's book with photographs of various animals and encourages children to see the beauty and detail of each animal in her book titled, *What Do You See When You Look at Me*?

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ILLINOIS CANCER DATA, CONTINUED

TABLE 3

Relative risk of cancers in the Dresden/Braidwood study area compared to Illinois statewide

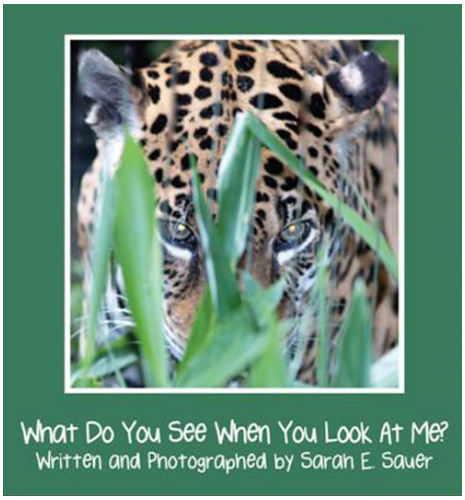
	1987-96	1997-2006	% Change
Oral	1.04	1.18	14.3
Colorectal	1.03	1.14	10.3
Lung	1.16	1.18	1.9
Breast	0.90	1.04	15.2
Cervix	0.91	1.10	20.1
Prostate	0.99	1.01	1.6
Urinary	1.05	1.20	13.4
Nervous	0.94	1.23	31.0
Leukemia	1.05	1.18	13.0
Other	1.01	1.09	7.5
Total	**1.02**	**1.10**	**8.1**

Relative Risk after Spills 1997-2006

- Braidwood & Dresden : Illinois Ratio
  - All Cancers Combined: 1.10
  - Leukemia: 1.18
  - Brain: 1.23
- 10% more likely to develop cancer living near plants
- 23% more likely to develop brain cancer near plants

SAUER INTERVIEW

CONTINUED FROM PAGE 7

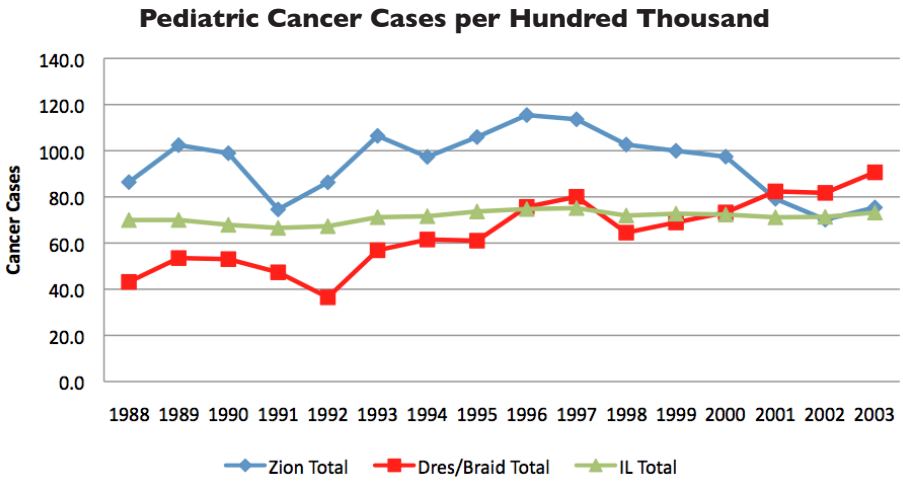


Arjun: If Sarah wants to say something here, she would be most welcome of course.

Sarah: When I was seven years old I was diagnosed with brain cancer. The surgery, chemo and radiation treatment were horrible. I lived in Illinois in the vicinity of the Dresden and Braidwood nuclear power plants. I, along with other children, became sick with cancer. My parents moved me away from the area after many people, including officials in Washington DC, told my parents it was not safe to live there. My parents and I have been to Washington DC to speak to various government officials and fight for the right for kids to live in a healthy environment and not to have to be exposed to low levels of radiation on a daily basis. I spoke to the National Academy of Sciences twice to remind them of who they are doing the health study for and that me and all the other kids who live(d) near nuclear power plants and got cancer are not just a statistic. Cancer may have taken many things from me but it did not take away my love for life. All of life is very precious and we need to make sure that everyone, especially the children have a safe and healthy world to grow up in.

IEER would like to offer Sarah's book for $20, including shipping. It will be signed by her. The family will generously donate half the funds to IEER. You can order the book at: http://ieer.org/resource/commentary/on-life-near-two-nuclear-power-plants-in-illinois.

ILLINOIS CANCER DATA, CONTINUED



Pediatric Cancer - Total:

- Rate for 10 years before (1986-95) versus 10 years after (1996-05) change in exposure
- **Zion** showed pediatric cancer rate **decreased 9.7%** after closure of plant
- **Braidwood & Dresden** showed pediatric cancer rate **increased 55%** after leaks began
- Using 1987-96 vs. 1997-06 showed 13% decrease at Zion and 38% increase at Braidwood & Dresden

Reference Man (used to determine acceptable levels of exposure):

- Male
- 20-30 years old
- Weight 70 kg (154 lbs)
- Height 170 cm (5 ft 7 in)
- Caucasian

Each line in the data collected represents a person. This is Sarah Sauer.

60447	2	8	1	1	19972001	41.4552	-88.265

Memorandum to NRC Chairman Allison Macfarlane

On November 13, 2012, IEER's President Dr. Arjun Makhijani had the opportunity to meet with incoming NRC Chairman Dr. Allison Macfarlane. Following this meeting, Dr. Makhijani sent a memorandum to Chairman Macfarlane that included some additional notes and references on the topics they discussed. The content of this memorandum is posted to the IEER website and a summary is reproduced below:

To: Dr. Allison Macfarlane, Chairman, NRC

From: Arjun Makhijani

Subject: Some notes and references regarding our meeting on November 13, 2012

Thank you very much for having taken the time to meet with me yesterday. This is to follow up and provide you with some notes and some URLs for reference to make it easier for you and your staff to pursue any of these points in more detail, should you wish to do so. My recommendations are in bold.

Our meeting covered three topics:

1. **Pilot epi studies:** Some issues relating to the pilot epidemiological studies that the NRC authorized a National Academies panel to pursue following the publication of the panel's feasibility study and recommendations earlier this year.
2. **Radiation risk communication** by the NRC.
3. **10 CFR 61:** Some concerns that I have regarding the way that the NRC has been handling some scientific issues relating to low-level waste, including the potential revision of 10 CFR 61.

1. Pilot epi studies

I really appreciate that the NRC has decided to fund the pilot studies. However, IEER recommended that only the case control study should be done. This option was not discussed in the NRC's memorandum authorizing the studies dated October 5, 2012 (SECY-12-0136). My comments on the feasibility study are available online.[1]

I am not asking for a revision of the NRC mandate to proceed with both the case control and the ecologic pilot studies. However, it would be useful, and may help avoid the controversies that are very likely to attend upon the ecologic study, **if the panel were to pursue and publish its work in two parts – the children's case control study first and then the ecologic study, with due attention to the lessons learned from the case control study.**

It is important for the pilot study to consider the effects of more than one nuclear power plant if people are living in the shadow of more than one. Specifically, Dresden and Braidwood should be considered together, because there are people affected by both – like the Sauer family. Sarah Sauer had brain cancer at the age of 7; she was operated on and lives with severe after effects. Her father, a medical doctor, has done an important preliminary analysis of childhood cancer data in the area, despite facing many obstacles. He presented his work to the National Academies panel, and you can access his slides online.[2]

Tritium is likely to be a critical radionuclide for estimating fetal dose from nuclear power plant operation. IEER concluded some time ago that the ICRP's method of attributing the mother's uterine wall dose from tritium (and from alpha-emitting radionuclides) to the embryo during the first eight weeks of pregnancy is incorrect. Though I have not yet looked at it specifically, it seems to me that the problem also extends to carbon-14, which was also identified as a key radionuclide in the feasibility study. The issue of a scientifically defensible approach for fetal dose estimation, especially during the early part of pregnancy, needs to be addressed because it is very important for a credible children's case control study that is geared (rightly so, in my opinion) to the mother's place of residence at the time of the birth of the child. IEER's report, *Science for the Vulnerable*, which briefly covers this issue (especially see pages 73 and 85) can be downloaded from the IEER website.[3]

I recommend that the NRC request the EPA's Science Advisory Board or the National Academies Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation to provide it with scientific advice as expeditiously as possible on how fetal doses, including in the first eight weeks, from alpha emitters and relatively low-energy beta emitters, particularly tritium and carbon-14, should be calculated. This problem should also be addressed by the National Academies pilot study in the course of its work.

A related data problem is that the NRC does not require monitoring of tritium in rainwater, though this is recognized as a potential issue by at least some in industry. This could be a crucial exposure pathway especially during pregnancy, notably for people with private wells. In 2006, Ken Sejkora of Entergy Nuclear Northeast (Pilgrim Station) estimated that under adverse weather conditions, episodic releases could result in concentrations as high as 36 million pCi/L – 180 times the drinking water limit close to the stack (probably onsite, though this is not explicitly stated). Sejkora used a source term of 1 Ci/day.[4] While this choice is on the higher side of routine releases (for one sample year, 2004) I have looked at, even higher tritium source terms releases from US nuclear power plants have been measured. For instance, the Palo Verde plant reported 2,123 curies of tritium releases to the atmosphere in 2004 (all three reactors).

I recommend that the NRC require routine monitoring of

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CONTINUED FROM PAGE 9

rainwater around commercial nuclear reactors. The NRC should also encourage nuclear power plant owners to consider making funds voluntarily available to private well owners nearby in case the well owners want to have their water tested for tritium and other radionuclides emitted from nuclear power plants.

2. NRC's radiation risk communication

The NRC's radiation risk communications with the public leave a lot to be desired. It would be extremely helpful if the NRC's statements to the public on radiation risk clearly stated that the best scientific understanding of low level radiation risk for cancer is that there is no safe level of exposure. Only zero exposure results in zero cancer risk. Instead, of explaining that this is the basis of its own regulations and those of the EPA, the NRC's website states the following:

"In general, a yearly dose of 620 millirem from all radiation sources has not been shown to cause humans any harm."[5]

The 620 millirem total includes natural background, indoor radon and even medical radiation, the risk of which is now a matter of considerable public concern, despite the benefits that may accrue from it to the person getting the radiation dose. Moreover, an annual US population exposure at this level per person would be associated with over 200,000 excess cancers per year, using an average risk coefficient for cancer incidence of 0.11 cancers per person-Sv. The statement on the NRC's website seriously misleads the public and, in my opinion, negatively affects public confidence in the NRC. **I recommend that it be replaced with a simple statement that reflects radiation risks as presented in the BEIR VII or EPA's Federal Guidance Report 13 (FGR-13). The word "safe" should be not be used in the NRC's public pronouncements about radiation.**

3. 10 CFR 61

I have long thought that waste classification should be made more rational; as you know, it is a widely held view. However, revising the low-level waste rule should not become an occasion to loosen radiation protection or to make scientifically indefensible calculations.

First, the present Subpart C of 10 CFR 61 limits annual doses to the whole body or to any organ, except the thyroid, to 25 millirem per year; the thyroid dose limit is 75 millirem per year (10 CFR 61.41). In public documents and statements, such as SECY-08-0147, the NRC has indicated that the organ dose requirement was not addressed in compliance modeling because using only the total effective dose equivalent (TEDE) is "modern" science. In fact, the most recent science of internal dosimetry is based on committed organ doses – as evidenced in the EPA's FGR-13, which is its current guidance document. The internal dose portion of the TEDE is in fact derived from organ doses by attributing weighting factors to various organs, which have changed from time to time. It is much more sensible and scientific to rely on organ doses for internal doses than on an imputed whole body effective dose. TEDE is a useful concept for regulation, and I am not objecting to its use in compliance assessment, especially since it allows combining external and internal dose into a single number, which enables efficient compliance assessment. However, organ dose limits are central to existing radiation protection standards, especially for radionuclides that have preferred target organs, such as actinides, radioiodines, and strontium-90. By all means let's go from ICRP 2, which dates from the late 1950s, to FGR-13, but the NRC should not use it as an occasion to relax radiation protection. It would be especially offensive if existing radiation protection were to be relaxed under cover of modernizing the science. **Organ doses as defined in FGR-13 must be included in radiation protection rules, including in any revision of 10 CFR 61 Subpart C. The present numerical limits should be maintained, if not tightened. Since the rule is being revised, it should explicitly define a "member of the public" for purposes of compliance assessment as including males and females and people of all ages from infants on up.**

My comments on SECY-08-0147 are at http://ieer.org/resource/testimony/depleted-uranium-waste-nrc-wrong/.

Second, SECY-08-0147 also has a number of other problems such as million-year performance estimates for shallow land burial and other dubious assumptions, including achievement of the required site stability for the duration. This provides one argument for limiting the period of performance. **But if the period of performance for low-level waste disposal is to be limited (at present there is no limit in Subpart C), then there should be *strict limits on both the concentrations and the total curie amounts of long-lived radionuclides* that can be disposed of in a facility licensed under 10 CFR 61.**

I am taking the liberty of expanding on my comments yesterday on this point. One way to set these limits could be to examine a hypothetical worst-case pulse release of the entire inventory of long-lived radionuclides into the environment in various ways immediately after the end of the period of performance. The limits for long-lived radionuclides could be set so that the dose criteria would not be exceeded with any combination of long-lived radionuclides or release modes. This could allow upper curie limits to be derived in a scientifically reasonable way that would also ensure compliance with dose criteria. **In this context, radionuclides with half-lives of more than ten years should be defined as long-lived. My reasoning is that ten such half-lives is a reasonable period for assuming the existence of institutional controls. All other low-level wastes, including depleted uranium from enrichment plants and Greater-than-Class-C waste as currently defined should be designated for deep geologic disposal.** Two IEER reports on the LES proceeding which contain technical details on DU disposal are on the IEER website.[6] These are redacted public versions. The NRC's files on the 2004-2005 LES proceeding should contain the unredacted versions.

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It Pays to Increase your Jargon Power with Dr. Egghead!

1.Erg
a. The typical response of a teenager to any question about their day.
b. A Nile crocodile's mating call
c. A unit of energy equal to 100 nanojoules. That is a pretty small amount of energy. It takes about 1,000 ergs of work (mechanical energy) to lift a one-gram feather by one centimeter (about 0.4 inches).

2. Rem
a. A phase of sleep associated with deep sleep and dreaming.
b. An abbreviation of the word "remember" used in texting, as in "totes rem 2 txt l8r!"
c. A measure of the biological damage of a given absorbed dose of radiation which takes into account the varying ways in which ionizing radiations transfer their energy to human tissue. A rem is derived by multiplying rads by the "quality factor" of the type of radiation in question.

3. Rad
a. Something stupendous and wonderful.
b. A crow's call in Finnish.
c. A unit of absorbed dose of radiation, in other words, a measure of the amount of energy deposited in a specific mass of tissue. One rad equals 100 ergs per gram. There are about 28 grams per ounce.

4. Sievert
a. Slang used by French-Germans to describe environmentalists.
b. A French environmentalist group
c. A unit of equivalent absorbed dose equal to 100 rem, abbreviated "Sv"

5. Gray
a. The name of the god of somber ideas
b. A new hip hair coloring for twenty-somethings
c. A unit of absorbed radiation dose equal to 100 rad, abbreviated "Gy"

6. Curie
a. A spice commonly used in Indian cuisine
b. A tiny medical cure.
c. Unit of radioactivity equal to the radioactivity of 1 gram of radium -226. It is equal to 37 billion disintegrations per second.

Answers: 1. c, 2. c, 3. c, 4. c, 5. c, 6. c

MEMO TO NRC CHAIRMAN

CONTINUED FROM PAGE 10

Third, in the course of the LES licensing, both the NRC staff and the company's experts declared a report to be scientifically sound even though it contained a result that would allow the disposal of more U-238 than the weight of the Earth *per gram* of Utah soil. There were also other problem results. The report in question is

D. Baird, M.K. Bollenbacher, E.S. Murphy, R. Shuman, and P.B. Klein, *Evaluation of the Potential Public Health Impacts Associated with Radioactive Waste Disposal at a Site Near Clive, Utah,* Rogers and Associates Engineering Corporation, June 1990 (RAE-9004/2-1).

Please see the uranium-238, thorium-232, plutonium-239, and plutonium-242 results on p. 5-13. The allowable concentrations for these radionuclides were reported at physically impossible levels – all more than 5.0E37 picocuries per gram of soil, implying masses many orders of magnitude larger than a gram. I also wrote a report that was submitted to Utah's DRC for an IEER client, HEAL Utah, that included this point.[7]

The NRC should insist on scientific integrity and quality assurance in its own work and that of the agreement states, especially in documents having to do with licensing. That has not happened in this case despite the truly fantastic nature of the errors and the fact that the issue has been raised in several NRC forums, including formal oral testimony, and with the State of Utah, over a period of more than seven years. There has been no substantive response either from the NRC or the Utah Division of Radiation Control – at least none has so far been communicated to me.

ENDNOTES

1. See: http://ieer.org/resource/testimony/ieer-analysis-cancer-risks-populations/

2. See http://dels.nas.edu/resources/static-assets/nrsb/miscellaneous/Sauer_morning_present.pdf

3. Arjun Makhijani, Brice Smith and Mike Thorne. *Science for the Vulnerable: Setting Radiation and Multiple Exposure Environmental Health Standards to Protect Those Most at Risk.* Takoma Park, MD: Institute for Energy and Environmental Research, October 19, 2006. On the Web at http://ieer.org/resource/reports/science-vulnerable-setting-radiation.

4. Ken Sejkora, *Atmospheric Sources of Tritium and Potential Implications to Surface and Groundwater Monitoring Efforts*, Entergy Nuclear Northeast – Pilgrim Station, presented at the 16th annual RETS-REMP Workshop, Mashantucket, CT, 26-28 June 2006. The link is at http://hps.ne.uiuc.edu/rets-remp/presentations2006.htm.

5. http://www.nrc.gov/about-nrc/radiation/around-us/doses-daily-lives.html

6. See: http://ieer.org/resource/reports/costs-risks-management-disposal/

7. See: http://www.radiationcontrol.utah.gov/Rules/docs/2008/appB_com.pdf

Dear Arjun

Dear Arjun,

How does radioactivity get loose from a reactor and will it hurt me?

— Agitated in Arizona

Dear Agitated:

People used to think that radioactivity was when President Franklin Delano Roosevelt gave his fireside radio addresses between 1933 and 1944. But nuclear bombs and nuclear power changed all that. Nowadays it means stuff emanating from nuclear weapons and nuclear power plants that gives off types of radiation named after the Greek alphabet – alpha radiation (energetic helium nuclei), beta radiation (energetic electrons and positrons), and gamma radiation (energetic photons, which are quanta or "particles" of light).

Radioactivity "gets loose" from a reactor, as you put it, in many ways and forms – solid, liquid, and gaseous. For instance, filters trap radioactive materials (like cesium-137) when the water used to cool the reactor is cleaned. These filters have to be periodically changed. Used filters are quite laden with radioactivity; they are disposed of in shallow land burial sites for radioactive waste. From there it can migrate into the environment, for instance, by being carried down into the groundwater. There are several sites that are contaminated in this way due to "low-level" radioactive waste disposal.

Then there is the stack. Every nuclear power plant emits some radioactive gases, called noble gases, not because they are descended from Ivanhoe, but because they are inert. Then there is tritium. It is radioactive hydrogen and is formed in the reactor in the course of its operation. When combined with oxygen, it becomes radioactive water. Reactors emit this radioactive water vapor to the atmosphere. As a result it rains radioactive rain around nuclear power plants.[1] The degree of rainwater contamination in any one place depends on the weather, of course. If there is rainfall around the plant at the time of emissions, the concentration of tritium can exceed allowable drinking water standards by large multiples, even hundreds of times. The amounts of tritium emissions vary by reactor design and specific reactor; they also vary from year to year.[2] The Nuclear Regulatory Commission (NRC) does not require rainwater to be measured, even when there are private water wells around nuclear plants. Private water well quality is not regulated under the Safe Drinking Water Act.

Photo of the Class A low-level waste trench at the commercial low-level waste site at Hanford, Washington. (Source: Photo taken by NRC in August 1991. http://www.flickr.com/photos/nrcgov/7754370336/in/set-72157632911284013)

Carbon-14, a radioactive isotope of carbon, the building block of living molecules, like brain cells, and DNA, is also emitted as carbon-dioxide gas. Until 2010, the NRC not require that these emissions be measured.[3]

Tritium is also discharged (along with other radionuclides) whenever the primary cooling water is discharged into the environment – for instance, into rivers or into the cooling ponds where the water to condense the steam that drives the turbine(s) is stored. In this way it sometimes winds up in drinking water at levels generally under primary drinking water standards, which are calculated on an annual average basis. Some noble gases have short half-lives and decay into more dangerous, but smaller amounts of other radionuclides (like xenon-137 decays into cesium-137, which behaves like potassium in the body).

Then there are the tritium leaks. Groundwater under many reactor sites has been contaminated due to pipe leaks. At the Braidwood, Illinois plant, the leaks migrated offsite. (See my interview with Cindy and Joe Sauer and

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a statement from their daughter Sarah in this issue.)

If you get the idea that the measurements required of nuclear power plant operators reflect less than great vigilance, you are right. Moreover, tritium has been treated as not very dangerous as a radioactive material because when ingested by an adult male it passes through the system pretty quickly. But it also goes all over the body. It can make sperm radioactive. It can cross the placenta in a pregnant woman and irradiate the developing embryo/fetus. In my view this problem is especially important in the first many weeks of pregnancy when the fertilized egg is implanted on the uterine wall and when organs begin forming. For more details see *Science for Democratic Action Vol. 16, No. 1*[4] and the other work from our "Healthy from the Start" project[5].

It's also important to remember that repeated investigations by the National Academies (and others) have concluded that the best available information indicates that every incremental exposure to radioactive causes an increase in cancer risk.[6] This is also generally the basis of radiation protection regulations.

Further, leaks can and have occurred from spent fuel pools, where the irradiated used fuel from reactors is stored in large swimming pool like structures. The vast majority of long-lived radioactivity (defined as half-lives of years or more) at a nuclear power plant is in the spent fuel pools.

There are other points before fuel gets to the nuclear power plant and after the nuclear reactor is shut and decommissioned that radioactivity is let loose into the environment – at uranium mines and mills, and uranium processing plants at the front end; and at reprocessing plants at the back end if nuclear spent fuel is reprocessed to extract the plutonium in it, as it is in France and Britain, for instance. There you get further releases (carbon-14 dioxide, noble gases, tritium, and smaller amounts of other radioactive materials) into the air and water as well as more radioactive wastes building up. Spent fuel and highly radioactive waste from reprocessing will have to be disposed of eventually, posing risks there. Many reactor parts become radioactive in the course of reactor operation; decommissioned reactor parts are disposed of, posing risks of dispersal over the long run. In the United States, Native Americans have suffered disproportionately from the nuclear enterprise, for instance, in regard to uranium mining and milling.

Then there are the reactors that have been used to make bomb materials that have been fashioned into nuclear weapons. When these weapons were tested, including in the atmosphere, in space, and undersea (until 1963 by the United States, Soviet Union, and Britain; until 1975 by France, and until 1980 by China[7]), and also underground. Radioactive materials were dispersed worldwide, especially but not only from atmospheric tests. We still eat food and drink water slightly laced with radioactive debris from those nuclear-weapon tests.

Finally, there are accidents, the most infamous of which are Chernobyl (1986) and Fukushima Daiichi (2011). You can start with Wikipedia entries to learn about the wide, global actually, dispersal of radioactive materials due to these nuclear reactor disasters.

So dear Agitated, there's radioactive dispersal in many forms and by many paths, direct and indirect, from reactors; it is generally - except for bombs and accidents - considered to be at acceptable levels, or within existing radiation protection regulations, which aren't designed to protect pregnant women.

ENDNOTES

1. Ken Sejkora, *Atmospheric Sources of Tritium and Potential Implications to Surface and Groundwater Monitoring Efforts*, Presented at the 16th annual RETS-REMP Workshop, Mashantucket, CT, 26-28 June 2006, at http://hps.ne.uiuc.edu/rets-remp/PastWorkshops/2006/ppt/04%20Ken%20Sejkora%201.pps, from link at http://hps.ne.uiuc.edu/rets-remp/presentations2006.htm.

2. For more information about tritium releases, see *Science for Democratic Action* Vol. 16, No. 1 (August 2009). Online at http://ieer.org/article/science-for-democratic-action/volume-16-number-1/

3. National Research Council, Committee on the Analysis of Cancer Risks in Populations near Nuclear Facilities – Phase I, *Analysis of Cancer Risks in Populations near Nuclear Facilities: Phase I,* National Academy Press, Washington, D.C., 2012, at http://www.nap.edu/catalog.php?record_id=13388.

4. Online at http://ieer.org/article/science-for-democratic-action/volume-16-number-1/

5. Online at http://ieer.org/projects/healthy-from-the-start/

6. See Richard R. Monson (Chair) et al. *Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII – Phase 2*. Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation, Board on Radiation Effects Research, National Research Council of the National Academies. Washington, DC: National Academies Press, 2006. On the Web at http://www.nap.edu/catalog.php?record_id=11340; and Arjun Makhijani, Brice Smith and Mike Thorne. *Science for the Vulnerable: Setting Radiation and Multiple Exposure Environmental Health Standards to Protect Those Most at Risk.* Takoma Park, MD: Institute for Energy and Environmental Research, October 19, 2006. On the Web at http://ieer.org/resource/reports/science-vulnerable-setting-radiation. For more reports on this topic, visit http://ieer.org/projects/healthy-from-the-start/

7. Special Commission of International Physicians for the Prevention of Nuclear War and the Institute for Energy and Environmental Research, *Radioactive Heaven and Earth: The Health and Environmental Effects of Nuclear Weapons Testing In, On, and Above the Earth*, Apex Press, New York, 1991. On the Web at http://ieer.org/resource/books/radioactive-heaven-and-earth.

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