Radiological and Chemical Exposures at the Idaho National Laboratory that Workers May Not Have Known About —

How health is harmed by uranium, plutonium and other radiological and chemical exposures and possible nutritional support strategies

Environmental Defense Institute Special Report

By Tami Thatcher

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Brief Summary: Radiation workers and non-radiation workers at the Idaho National Laboratory since 1952 have been exposed to direct radiation sources, airborne radiological releases, contaminated soil, and contaminated drinking water — often without their knowledge. This report highlights historical operations at what is now called the Idaho National Laboratory and the contaminants. It discusses shortcomings in worker radiation protection standards and radiological monitoring. Former workers often have little idea of their potential exposures or health risks of the exposures. This report discusses the radiation exposure, ingestion and inhalation of radionuclides and exposure to chemical hazards that may be affecting their health — information that may be helpful as they receive care from health care providers to address their health challenges. The oxidative stress caused by ionizing radiation is described. The role of antioxidant systems, detoxification systems and nutritional support is also described which may aid a reader to seek further information to address chronic health issues.

Disclaimer: This report includes discussion of nutritional supplements but the information is educational and is not intended to diagnose, treat, or prevent any acute or chronic illness. This information is not intended to substitute for medical advice from a licensed health care provider. Also note that Environmental Defense Institute does not sell nutritional supplements nor does it receive money for advertisements. Possible harm can arise from use of supplements and licensed medical advice should always be sought before taking a new nutritional supplement.

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Executive Summary

I realized that I needed to write this report after I ran into a friend who I knew had been recovering from cancer treatments. What I hadn't known was that she had worked at the Idaho National Laboratory. "But I was just a secretary," she said. I asked her where at the INL she had worked. "Oh, several places — Test Area North and others..," she said. I tried to tell her that the water at Test Area North was found to be exceeding maximum contaminant levels for chemicals when first monitored in 1987 although the contamination began years earlier.

INL drinking water has historically been very contaminated with both chemicals and radionuclides depending on the particular facility and timeframe. The soil at TAN was also found to be very radiologically contaminated in the early 1990s during CERCLA cleanup investigations and found to require being hauled to another INL location. The soil contamination began in the 1950s with open air nuclear fuel melt testing. The cleanup soil excavations created new airborne contamination that spread the contamination for miles on and off the INL site.

The presence of highly radioactive spent nuclear fuel at various INL facilities creates elevated gamma radiation fields that are detected by aerial surveys and these elevated fields are considered "background" although they tend to roughly double normal background radiation levels.

So the facility and specific years worked there really matter— for both radiation and non-radiation workers at INL. My friend had no idea that she might have been chronically exposed to radiological and chemical toxins even though she was not a radiation worker.

So this report is an effort to provide an introduction into the world of potential radiological and chemical exposures at the Idaho National Laboratory to the former INL worker, their family, or their health professional. This effort will understandably be only the tip of the iceberg as the diversity of operations at INL since its inception in 1949 is immense, ranging from nuclear reactor operations, spent nuclear fuel reprocessing, other nuclear fuel separations processes, hot cell and glove box operations, open-air destructive nuclear fuel testing, various accidents and waste handling.

This report discusses the how ionizing radiation harms health, and provides some information about chemical exposures. And it goes further to discuss how someone living with chronic health issues that may be due to ionizing radiation and/or toxic chemical exposures might take steps to promote health. Readers need to seek licensed medical help and it is hoped that this report will help the medical professional better understand possible exposures that the patient may have encountered.

About the Author

Tami Thatcher is an Idahoan with roots in the Little Lost Valley. Her grandparent's ranch was located at the boundary of the INL between INTEC and Test Area North. There were radiation monitoring film badges hung on grandma's white picket fence — and she died of cancer. So understanding historical radioactive contamination, both airborne and in groundwater, has become a deeply personal interest. She has a Bachelor of Science degree in Mechanical Engineering from the University of Idaho and worked as a nuclear safety analyst at the Idaho National Laboratory. She is not most qualified person to write this — she just happens to be one of the few not compelled to hide the truth in order to preserve their career in the nuclear industry.

When it comes to understanding human health, it is her own health needs that have often provided the prompting for further study. After working 10 hour days at the INL with an hour and half commute each way, having undiagnosed sleep apnea, and being prescribed stronger and stronger stomach acid inhibitors, by 2006 the health challenges were many. This led to extensive learning, experimenting with nutritional supplements and considerable healing. At times the conventional medical professionals were absolutely necessary. But when the prescriptions of conventional medical practitioners could not be tolerated, discovering the path to health came from complimentary health approaches, including nutritional supplementation.

An extensive education of the human body ensued as she has studied acupressure meridians, cranial-sacral modality, and has practiced therapeutic massage and bodywork since 2010. Whether applying her knowledge to herself, her horses, or to family or clients, not a day goes by without increasing her appreciation — and awe — for the fabulous electrical and chemical machinery of the human body.

Radiological and Chemical Exposures at the Idaho National Laboratory

At the Idaho National Laboratory (formerly called the National Reactor Testing Station) radiological and chemical processes largely commenced in 1952 including the operation of nuclear reactors, spent nuclear fuel reprocessing and other nuclear fuel separations processes. These operations and others released airborne radiological contamination to blow in the wind. Enormous quantities of radiological and chemical contaminants were injected into the Snake River Plain aquifer to flow downgradient to other INL facilities (as well as offsite communities) and also to be unexpectedly sucked upgradient due to heavy pumping of production wells used to supply water at the facilities. Radioactive waste handling included trash pickup, loading wooden boxes with waste, stacking drums of waste and use of heavy equipment to scrape contaminated soils and haul contaminated soils from various locations at INL to other locations at INL in the name of "cleanup." Much of the shallowly buried radioactive and chemical wastes remain over the aquifer of which, despite the cleanup hype, very little is actually being retrieved. [1] [2] And radioactive waste continues to be buried over our Snake River Plain aquifer. [3]

The radionuclides and chemicals discussed in this report is not exhaustive. But it is hoped that it will be illuminating especially to workers like office workers or laborers who had little knowledge of the exposures they may have gotten in various ways:

- From direct radiation fields subtracted "as background" at any facility with spent nuclear fuel, operating reactors, or storage of radioactive materials or wastes;

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[1] U.S. Department of Energy, 2008. Composite Analysis for the RWMC Active Low-Level Waste Disposal Facility at the Idaho National Laboratory Site. DOE/NE-ID-11244. Idaho National Laboratory, Idaho Falls, ID and U.S. Department of Energy, 2007. Performance Assessment for the RWMC Active Low-Level Waste Disposal Facility at the Idaho National Laboratory Site. DOE/NE-ID-11243. Idaho National Laboratory, Idaho Falls, ID. Available at INL's DOE-ID Public Reading room electronic collection. See https://www.inl.gov/about-inl/general-information/doe-public-reading-room/

[2] See that the publically available administrative record for RWMC cleanup does not contain the assessment of radionuclide migration and radioactive doses after 10,000 years. The pre-10,000 year contaminant migration is artificially suppressed for the first 10,000 years and then rapidly escalates and stays elevated for hundreds of thousands of years. See the Administrative Record at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) documents for documents associated with this cleanup action, including "Record of Decision" documents and EPA mandated Five-year Reviews at http://ar.inel.gov or http://ar.icp.doe.gov

[3] US Department of Energy, "Environmental Assessment for the Replacement Capability for Disposal of Remote-Handled Low-Level Radioactive Waste Generated at the Department of Energy's Idaho Site," Final, DOE/EA-1793, December 2011. http://energy.gov/sites/prod/files/EA-1793-FEA-2011.pdf and see EDI's report "Unwarranted Confidence in DOE's Low-Level Waste Facility Performance Assessment – The INL Replacement Facility Will Contaminate Our Aquifer for Thousands of Years" at http://www.environmental-defense-institute.org/publications/rhllwFINALwithFigs4.pdf

- From drinking and showering in water from the aquifer laden with numerous radionuclides and chemicals, often exceeding what are now federal drinking water standards;
- From inhaling the air contaminated by lawn irrigation that uses contaminated aquifer water that can produce elevated levels of tritium and other contaminants;
- From inhaling radioactive particles released from routine stack releases, released from various past intentional or accidental radionuclide releases at the INL, and from other sources like radioactive waste uncovered during flooding and left to blow in the wind — from simply breathing the air, or perhaps while jogging around that open-air warm waste percolation pond.

Energy Employee Worker Compensation Claims at INL Often Denied

Many former INL workers may suspect that they have been exposed to radiation or chemicals and following illness may have applied to the Energy Employee Occupational Illness Compensation Program Act (EEOICPA) only to be denied. [4] The National Institute of Occupational Safety and Health (NIOSH) that administers the energy employee illness program, the EEOICPA, emphasizes that it uses claimant favorable modeling to determine whether working at INL likely caused the illness. But they have denied two-thirds of the claims by INL workers. Fortunately, there are now several radiation exposure cohorts that provide compensation for INL and ANL-W employees for certain years of employment without requiring radiation dose reconstruction to determine eligibility. [5]

NIOSH decides whether to approve or deny claims but has never taken a look at the drinking water contamination levels at various INL sites. If they had, they would have needed to fill-in-the-blanks on the contamination levels for the years that various contaminants were present but not monitored. No such report exists. Environmental Defense Institute has prepared two reports, however, that highlight some of the recorded levels of contamination in drinking water at INL and downgradient of the INL. [6] [7]

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[4] 42 USC 7384, The Act--Energy Employees Occupational Illness Compensation Program Act of 2000 (EEOICPA), as Amended and see the website for the Center for Disease Control, National Institute of Occupational Safety and Health, Division of Compensation Analysis and Support at http://www.cdc.gov/niosh/ocas/ and U.S. Department of Labor, Office of Workers' Compensation Programs, EEIOCPA Program Statistics, http://www.dol.gov/owcp/energy/regs/compliance/weeklystats.htm

[5] See the Idaho National Laboratory status at http://www.cdc.gov/niosh/ocas/ineel.html and see the portion of INL formerly ANL-W at http://www.cdc.gov/niosh/ocas/anlw.html

[6] Environmental Defense Institute report by Tami Thatcher, *The Hidden Truth About INL Drinking Water*, June 2015, http://environmental-defense-institute.org/publications/INLdrinkwaterR1.pdf

[7] Thatcher, T.A., Environmental Defense Special Report, *Tritium at 800 pCi/L in the Snake River Plain Aquifer in the Magic Valley at Kimama: Why This Matters*, 2017. www.environmental-defense-institute.org/publications/kimamareport.pdf

NIOSH did, however, conduct epidemiology comparing the health of INL workers to that of surrounding communities and they found that both radiation workers and non-radiation workers at the INL site had elevated illnesses. [8] NIOSH never sought to answer why.

The information in this report, unfortunately, is not likely to help these non-radiation workers or radiation workers obtain energy employee illness compensation because, officially, many of these workers have little or no record of significant radiation exposure and may not have been assigned a radiation badge. And this is despite the growing body of human epidemiological evidence that shows that the officially accepted models of radiation cancer risk underestimate the harm of ionizing radiation. [9] [10]

Chemical Exposures Difficult to Prove

Energy worker compensation also addresses chemical exposures, but the burden is typically on the worker to prove the exposure — which is nearly impossible given that no records exist that would accurately describe the chemical exposure. The many problems of providing adequate chemical monitoring apply at INL as they do at the Department of Energy's Hanford site in the State of Washington. [11] See this detailed 2014 Hanford Tank Vapor report [12] for an idea of the issues involved with inadequate protection of workers at Department of Energy facilities, historically and continuing. Many of the Hanford issues apply to the INL especially where chemical separations of nuclear fuels was conducted. Neither the worker nor the DOE contractor will have record of the levels of chemical vapors even after a tank burp incident occurs that promptly makes a worker ill.

Contaminated Drinking Water at INL Ignored

[8] "An Epidemiology Study of Mortality and Radiation-Related Risk of Cancer Among Workers at the Idaho National Engineering and Environmental Laboratory, a U.S. Department of Energy Facility, January 2005. http://www.cdc.gov/niosh/docs/2005-131/pdfs/2005-131.pdf and http://www.cdc.gov/niosh/oerp/ineel.htm and Savannah River Site Mortality Study, 2007. http:/ /www.cdc.gov/niosh/oerp/savannah-mortality/

[9] Richardson, David B., et al., "Risk of cancer from occupational exposure to ionizing radiation: retrospective cohort study of workers in France, the United Kingdom, and the United States (INWORKS), BMJ, v. 351 (October 15, 2015), at http://www.bmj.com/content/351/bmj.h5359 Richardson et al 2015] (And please note that studies of high leukemia risk in radiation workers and of ongoing studies to assess health effects of high and low-linear energy transfer internal radiation must also be studied in addition to this one on external radiation.)

[10] "Health Risks from Exposure to Low Levels of Ionizing Radiation BEIR VII – Phase 2, The National Academies Press, 2006, http://www.nap.edu/catalog.php?record_id=11340 The BEIR VII report reaffirmed the conclusion of the prior report that every exposure to radiation produces a corresponding increase in cancer risk. The BEIR VII report found increased sensitivity to radiation in children and women. Cancer risk incidence figures for solid tumors for women are about double those for men. And the same radiation in the first year of life for boys produces three to four times the cancer risk as exposure between the ages of 20 and 50. Female infants have almost double the risk as male infants.

[11] Till, J.E. et al., Radiological Assessment Corporation, for the Centers for Disease Control, "Final Report – The Feasibility of Performing a Chemical Dose Reconstruction Study at the INEEL," RAC Report No. 4-CDC-Task Order 1-1999-Final, September 1999. https://www.cdc.gov/nceh/radiation/ineel/taskorder1report.pdf

[12] Hanford Tank Vapor Assessment Report, SRNL-RP-2014-00791, Oct 30, 2014. http://srnl.doe.gov/news/releases/nr14_srnl-advisory-hanford-vapors-report.pdf

If NIOSH were to conduct the analyses necessary to estimate the drinking water contamination present at various INL sites in each year a worker may have been employed there, unfortunately, the radiation model NIOSH uses would underestimate the true health impact. And the additional stress on the body of the chemical contaminants in the water such as hexavalent chromium, carbon tetrachloride, etc, would not be recognized by NIOSH. In fact, the policy at NIOSH does not allow them to consider the combined effect of radiation and chemical exposure.

In 2016 NIOSH acknowledged inadequate monitoring of alpha emitters at the INL in some years, and so now workers qualifying under a special exposure cohort will not require a radiation dose reconstruction. But workers who do require a radiation dose reconstruction to determine compensation eligibility can be limited by the lack of adequate monitoring and even the deliberate falsification or destruction of records.

Evolving Radiation Protection Standards

Radiation protection standards in the 1950s allowed 15 rem annually, which over time was reduced to 12 rem and then 5 rem annually in the 1960s. Despite the modern international recommendation that workers receive no more than a total of 10 rem over 10 years (or an average 2 rem annually), in the US, 5 rem annually remains the radiation protection standard.

Internal contamination was not monitored at all or not monitored with any accuracy in the early years — and still isn't reliable. Radiation dose estimates have suffered from a lack of adequate monitoring programs and sometimes from a lack of desire to admit the full extent of the exposures, especially if the exposure bumped against or above radiation protection limits. The same DOE contractor who will be punished for exceeding federal radiation dose limits is in charge of evaluating the worker's radiation dose. The dose estimate can be pencil-whipped into oblivion all while claiming that official and approved methods of the International Commission on Radiological Protection (ICRP) were used.

Drinking water standards largely did not exist until the 1960s and then tended to fluctuate wildly once extensive contamination was discovered at INL. The standard for the allowable concentration of tritium, now 20,000 pico-curies/liter (pCi/L) was allowed to be as high a 100,000,000 pCi/L at the INL site from 1964 to 1968. The standards on the DOE site have typically allowed 10 to 100 times more contamination than allowed offsite. While gross alpha and gross beta were monitored in drinking water, iodine-129, a beta emitter, with its very low allowable concentration limit now of 1 pC/L may have likely been exceeded for many years. So workers at Central Facilities were drinking elevated levels of tritium, gross alpha, gross beta, and iodine-129 in addition to hexavalent chromium and other chemicals. At the INL, the additive effect of multiple contaminants in drinking water was ignored. [13]

In recent years, tritium monitoring detected that the sprinkling of lawns at Central Facilities was increasing the levels of airborne tritium. Of course! How could it not? But just think of the

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[13] Environmental Defense Institute report by Tami Thatcher, *The Hidden Truth About INL Drinking Water*, June 2015, http://environmental-defense-institute.org/publications/INLdrinkwaterR1.pdf

levels in the 1950s and 1960s when the levels of tritium in the aquifer beneath Central Facilities was much higher, five times the current concentration limit of 20,000 pCi/L. A woman working at Central Facilities may have been helping wash the coveralls used by radiation workers around the site. Radioactively contaminated clothing was being mixed together and then washed with radioactively contaminated water! I was radworker qualified and I saw that the savvy radiation worker surveyed the freshly cleaned coveralls before putting them on, and opted for new coveralls if possible.

Chemical Contamination in the Aquifer Not Monitored Until 1987

Despite US Geological Survey monitoring of the aquifer since 1949, the view that the aquifer was a economical disposal solution, the evolving regulatory standards in the early years, and the secrecy surrounding nuclear research especially as related to nuclear weapons production had created a system that intermittently monitored contaminants, sometimes decades after the waste was introduced.

Chemical contamination was injected into the aquifer from the 1950s through the 1980s but was not monitored by the USGS until 1987. Bottled water was then given to workers but only if the contamination of a single contaminant exceeded contamination limits. The combination of radiological and chemical contaminants was rarely, if ever, considered. And even when contaminants were monitored, the workers and public were not told the truth about the spread of the aquifer contamination throughout the INL and downgradient from the INL site.

The extent of chemical and radiological contaminants from INL waste water injection wells and percolation ponds is discussed in EDI reports *The Hidden Truth About INL Drinking Water* and *Tritium at 800 pCi/L in the Snake River Plain Aquifer in the Magic Valley at Kimama: Why This Matters*, [14] [15] The range of chemicals prevalent in drinking water is discussed in this report. Also discussed are some reasons why simply staying below maximum contaminant levels (MCLs) is not enough to assure adequately safe drinking water (see the last section of this report).

Radiological Airborne Releases Underestimated-

Beginning in the 1950s, millions of curies were released from stacks and open-air destructive nuclear fuel testing, fuel reprocessing, and accidents. When then State Governor Cecil Andrus asked what had been released, the Department of Energy had to begin a review of the accidents, tests and various operations they had conducted to try to estimate what they had released. DOE had long been assuring people that no serious radiological releases had taken place based on

[14] Environmental Defense Institute report by Tami Thatcher, *The Hidden Truth About INL Drinking Water*, June 2015, http://environmental-defense-institute.org/publications/INLdrinkwaterR1.pdf

[15] Thatcher, T.A., Environmental Defense Special Report, *Tritium at 800 pCi/L in the Snake River Plain Aquifer in the Magic Valley at Kimama: Why This Matters*, 2017. www.environmental-defense-institute.org/publications/kimamareport.pdf

various environment samples of sage, soil, rabbit thyroids, and by film badge. But they didn't actually know how many curies they had released nor of what radionuclides.

The estimates of the 1991 INEL Historical Dose Evaluation [16] continue to be found in error and significantly underestimate what was released. [17] [18] [19] Theoretical and idealized modeling of the releases were used for estimating the releases for the 1991 INEL HDE without using environmental monitoring to confirm the estimates — except for the 1961 SL-1 accident in which the **theoretical modeling was shown to underestimate the release**. In fact, many of the environmental monitoring records were deliberately destroyed after the 1991 report was released.

The source documents for the INEL HDE are in fact part of the Human Radiation Experiments collection of DOE documents. Why? Because there was enough information available for the DOE to know that showering nearby communities and their farms and milk cows with radiation really wasn't a good for their health. The INL (formerly the NRTS, INEL and INEEL) takes up dozens of volumes of binders in the DOE's Human Radiation Experiments collection and that isn't including the boxes of documents no one can get access to or the records that were deliberately disposed of. [20]

INL airborne releases included a long list of every fission product that exists but few were monitored. For brevity, this report focuses mainly on short-lived iodine-131, long-lived I-129, tritium, strontium-90, cesium-37, plutonium, and uranium. The radionuclides that were released to the air, often completely unfiltered, blew with the prevailing winds. But it is important to understand that typically the wind direction reverses at night. The winds that carry radioactive effluent toward the northeast by day reverse and carry the effluent toward the southwest at night.

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[16] US Department of Energy Idaho Operations Office, "Idaho National Engineering Laboratory Historical Dose Evaluation," DOE-ID-12119, August 1991. Volumes 1 and 2 can be found at https://www.iaea.org/inis/inis-collection/index.html p. 40

[17] Risk Assessment Corporation, "Identification and Prioritization of Radionuclide Releases from the Idaho National Engineering and Environmental Laboratory," October 8, 2002, https://www.cdc.gov/nceh/radiation/ineel/to5finalreport.pdf See p. 117, 118 for SL-1.

[18] SENES Oak Ridge, "A Critical Review of Source Terms for Select Initial Engine Tests Associated with the Aircraft Nuclear Program at INEL," Contract No. 200-2002-00367, Final Report, July 2005. http://www.cdc.gov/nceh/radiation/ineel/anpsourceterms.pdf See p. 4-67 for Table 4-13 for I-131 estimate for IET's 10A and 10B and note the wrong values for I-131 are listed in the summary ES-7 table.

[19] CDC NIOSH, "NIOSH Investigation into the Issues Raised in Comment 2 for SCA-TR-TASK1-005," September 3, 2013. https://www.cdc.gov/niosh/ocas/pdfs/dps/dc-inlspcom2-r0.pdf See p. 3 stating various episodic releases underestimated by the INEL HDE: IET 3, IET 4 and IET 10.

[20] February 1995, the Department of Energy's (DOE) Office of Human Radiation Experiments published *Human Radiation Experiments: The Department of Energy Roadmap to the Story and Records* ("The DOE Roadmap"). See also the INL site profile on Occupational Environmental Dose: http://www.cdc.gov/niosh/ocas/pdfs/tbd/inl-anlw4-r2.pdf) Most of the documents in the DOE's Human Radiation Experiments collection remain perversely out of public reach. Documents are said to be stored at the INL site, out of state in boxes, [Good luck with getting these documents via the Freedom of Information Act] and in the National Archives. I found that retrieving documents from the National Archive would require extensive fees for searches and copying. Where is the transparency in creating a document collection that cannot be viewed by the public?

The shifting winds ensure a generous offering of airborne effluent from Minidoka to Blackfoot, from Arco to Rexburg and to Idaho Falls. Wind isopleths showing the radionuclide concentrations are often lopped off south of the INL despite the air concentrations remaining high. Long-lived particles land in the soil and then can be resuspended to blow another day.

Problems with Worker Radiation Dose Estimates

Workers internal radiation exposures from inhalation and ingestion are still not being explained to workers. Too often, the methodologies used are complex — but complexity tends to obscure how highly uncertain the radiation dose estimates are from internal exposures. These internal radiation dose estimation methods were never intended for individual doses — they were intended for population dose estimates. And workers are not monitored with appropriate medical monitoring methods that would be appropriate for monitoring an individual's health. Instead, highly inaccurate and uncertain internal radiation dose estimation methods are manipulated to reduce the radiation doses.

Long ignored uranium health risks are discussed here because the health risks of uranium from fuel that has been melted, reprocessed or oxidized, whether enriched or depleted in uranium-235 in comparison to natural uranium, can be more insoluble and more harmful in the body than natural mined or milled uranium. Uranium is both a radiological hazard by alpha particle, by beta and gamma particles from decay progeny, and a heavy metal toxin. There are numerous adverse health risks in addition to more well known kidney failure and cancer risks, as Gulf War veterans exposed to depleted uranium have learned. Birth defects have also been prevalent in the children of people exposed to depleted uranium from the 1991 Gulf War. [21]

Health Risks From Ionizing Radiation Extend Beyond Cancer Risk

Ionizing radiation produces a state of high oxidative stress, damaging cellular membranes as well as DNA and other essential cellular material. The high level of oxidative stress depletes the body's antioxidant defenses. Chemical exposures, through different processes, also cause high oxidative stress. Many chronic illnesses are caused by high oxidative stress.

Some cellular processes most disrupted by radiological and chemical exposures are discussed because it is vital to help the sufferer understand these symptoms and what can be done to help restore depleted nutritional stores. The reader may begin to understand that antioxidants and various vitamins, minerals and amino acids can be seriously depleted as the body must cope with the challenge of ionizing radiation and heavy metals at a cellular level.

For chronic and non-lethal doses of radiation, the effort spent to understand how cellular processes work to detoxify the body, how to recognize the symptoms of depletion, and how

[21] Rosalie Bertell, International Journal of Health Services, "Depleted Uranium: All the Questions About DU and Gulf War Syndrome Are Not Yet Answered," 2006. p. 514 https://ntp.niehs.nih.gov/ntp/roc/nominations/2012/publiccomm/bertellattachmentohw.pdf

nutrition and supplementation may help — has the potential for health benefits for some individual with chronic exposures.

There are many causes of insomnia, rapid heartbeat, and fatigue. But former INL workers need to understand that ionizing radiation, chemical and heavy metals exposure could be the cause or contributor to this array of symptoms as well as other symptoms, long before a cancer develops. It is important for medical practitioners, even those well versed in radiation illnesses, to grasp the full range of health issues and the extent of nutritional depletion that can be caused by exposures to ionizing radiation and other toxins.

Radiological Hazards at the INL

Radiation workers — and I was one of them — are taught primarily that there are three kinds of radiation: gamma ray, beta ray and alpha particles (see Table 1). They are taught that gamma rays are penetrating and may require lead, concrete or many feet of water for shielding; beta rays only travel a few feet and may be easily shielded; and alpha particles are shielded by a sheet of paper. “Just obey the posted signs, and you will be protected.” “Most workers radiation doses will be considerably below the annual limit of 5 rem annually” and by this it is to be inferred that 5 rem annually would be a dose low enough to not cause harm. But in 10 years, this accumulated 50 rem dose would hold significant cancer risk, even by industry-favorable estimates of harm.

Workers are not told that the level of gamma radiation where they work near spent fuel storage and nuclear reactors may be higher than the normal background gamma level and that this elevated level is subtracted from their badges as though it were normal. Over time, this elevated gamma exposure adds up.

Table 1. Ionizing Radiation Particles and Rays.

Particle or Ray	Common Name	Symbol	Charge	Atomic Mass Units	Penetrating Power[a]	Energy Range[b, d]
Helium nucleus	Alpha particle	α	+2	4	0.02 - 0.04 mm	3-9 MeV
Electron	Beta particle	β	-1	0.00055	0 - 4 mm	1-3 MeV
Gamma ray	Gamma ray	γ	0	0	1 - 20 cm	0.01 – 10 MeV
X-ray	X-ray		0	0	0.01 – 1 cm	0.1 – 10 keV
Neutron[c]	Neutron	n	0	1		1 meV - 20 MeV

Source: Bettelheim et al., “Introduction of General Organic & Biochemistry, 6th ed.” Harcourt College Publishers, 2001.

a. penetrating power at which half the radiation has been stopped in water.

b. The electron volt is a non-SI unit used in nuclear chemistry. 1 keV = 1000 eV. 1 MeV (mega or 1,000,000 electron volts) = 1.602 E-13 joules = 3.829 E-14 calories. (1000 calories in a Calorie used in food labeling.)

c. INL workers may have unrecorded or underestimated neutron exposure near operating reactors, or fissile material handling which are penetrating of the human body.
d. The energy range for neutrons is based on I. Thieery-Chef et. al., *Radiation Res*., "Dose Estimation for a study of nuclear workers in France, the United Kingdom, and the United States of America: Methods for the International Nuclear Worker Study (INWORKS)., June 2015.

While the penetrating power of an alpha particle is low, the energy imparted to tissue when in the body is very high. Many alpha emitters such as plutonium and uranium decay not only by alpha decay but also by beta and gamma emission. Beta particle monitoring is often particularly inaccurate. Gamma ray monitoring is based on badges worn on the collar but the source of radiation may be beneath the workers feet as is the case when workers work over spent nuclear fuel pools. Workers at INL have also had neutron dose from the Materials Test Reactor neutron beam and from concentrated fissile materials. Historical monitoring of neutron dose was inadequate.

Workers need to keep in mind that, despite what they may have been taught:

- The cancer risk is not reduced when radiation doses are received in small increments, as the nuclear industry has long assumed. [22]
- Despite the repeated refrain that the harm from doses below 10 rem cannot be discerned, multiple and diverse studies from human epidemiology continue to find elevated cancer risks below 10 rem and from low-dose-rate exposure. [23]
- The adverse health effects of ionizing radiation is not limited to the increased risk of cancer and leukemia. Ionizing radiation is also a contributor to a wide range of chronic illnesses including heart disease and brain or neurological diseases.

Workers take cues from their management that they should not be concerned about the tiny and easily shielded beta and alpha particles. The biological harm that ionizing radiation may cause to DNA is mentioned but it is emphasized that usually the DNA simply are repaired by the body. And the training will mention that fruit flies exposed to radiation passed genetic mutations to their offspring but US radiation workers are told that this phenomenon has never been seen in humans even though, sadly, the human evidence of genetic effects has continued to accumulate. Birth defects and children more susceptible to cancer are the result.

[22] Richardson, David B., et al., "Risk of cancer from occupational exposure to ionizing radiation: retrospective cohort study of workers in France, the United Kingdom, and the United States (INWORKS), BMJ, v. 351 (October 15, 2015), at http://www.bmj.com/content/351/bmj.h5359 Richardson et al 2015 This cohort study included 308,297 workers in the nuclear industry.

[23] US EPA 2015 http://www.regulations.gov/#!documentDetail;D=NRC-2015-0057-0436 . For important low-dose radiation epidemiology see also John W. Gofman M.D., Ph.D. book and online summary of low dose human epidemiology in "Radiation-Induced Cancer from Low-Dose Exposure: An Independent Analysis," Committee for Nuclear Responsibility, Inc., 1990, http://www.ratical.org/radiation/CNR/RIC/chp21.txt And see EDI's April 2016 newsletter for Ian Goddard's summary and listing of important human epidemiology concerning low dose radiation exposure.

Gulf War veterans who inhaled depleted uranium have children with birth defects at much higher than normal rate. The same kinds of birth defects also became prevalent in the countries were citizens were exposed to DU. There are accounts to suggest that the actual number of birth defects resulting from the World War II atomic bombs dropped on Japan and by weapons testing over the Marshall Islands have been underreported. The Department of Energy early on made the decision not to track birth defects resulting from its workers or exposed populations. But people living near Hanford and near Oak Ridge know of increased birth defects in those communities.

In radworker training, there may be discussion of the fact that international radiation worker protection recommends only 2 rem per year, not 5 rem per year. There is no mention of recent human epidemiology showing the harm of radiation is higher than previously thought and at low doses, below 400 mrem annually to adult workers, increased cancer risk occurs.

There is no mention of the oxidative stress caused as ionizing radiation strips electrons off atoms or molecules in the body at energies far exceeding normal biological energy levels. And there is no discussion explaining the harm of inhaling or ingesting radioactive particles of fission products such as cesium-137, strontium-90, or iodine-131; of activation products such as cobalt-60; or transuranics such as plutonium and americium; or of the uranium itself.

Radiation workers thought to be exposed to inhalation of radionuclides are required to provide urine and fecal samples for bioassay. But these workers often never see the results and even if they see them, the results and possible risks are not explained. In fact, workers have in the past been asked to sign documentation saying they have shown the results of bioassay when actually the documents are being withheld.

A worker may seek to obtain documentation concerning their internal radiation dose by using a Freedom of Information Act request. The request will often be initially denied, thus requiring the time and effort to make an appeal, which may be granted. However, the worker is now likely to be branded a trouble-maker. So even when an internal radiation dose has been conducted, a worker is unlikely to know what the results were. And knowing the cancer risk increase from the internal radiation is only part of the story. The numerous other adverse health effects of incorporating radioactive particles into the body are typically not mentioned and may not even be known by the personnel involved with radiation health programs.

In the 1950s through the 1970s at least, the intentional releases of fission products including iodine-131 releases were common. Iodine-131 was measured in rabbit and antelope thyroids at the INL. Iodine-131 is short-lived but in addition to being inhaled, the fallout on pastures contaminants the grass causing cows milk and goat milk to be contaminated. The iodine-131 was then consumed by children and adults. The iodine-131 was absorbed by the thyroid and this tiny organ of the body received a hefty gamma radiation dose from it. The INL releases were in addition to the generous releases of iodine-131 from Department of Energy weapons testing at the Nevada Test Site and by other weapons testing by the US and by other countries. An INL worker drinking the water at INTEC or Central Facilities might also have ingested long-lived Iodine-129. If a person's thyroid is lacking in the iodine needed for it to make thyroid hormones, more radioactive iodine will be taken up by the thyroid. That is why potassium iodide tablets were to be made available in the case of elevated levels of radioactive fallout from weapons testing or melting fresh nuclear fuel. The thyroid full of normal iodine would not absorb as much radioactive iodine. Metabolic health is adversely affected by a thyroid full of radioactive iodine, making the person more vulnerable to a wide variety of illnesses.

Toxic Soup in the Drinking Water

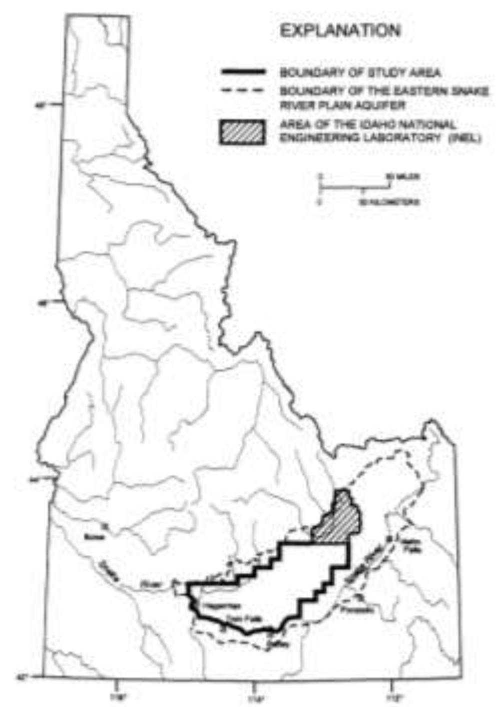

Figure 1. Location of the study area, between the Idaho National Engineering Laboratory and Hagerman, Idaho.

Waste water from nuclear fuel reprocessing, other fuel separations processes and reactor operations from the historical operations at the Idaho National Laboratory included 31,000 curies of tritium between 1952 and 1990. The waste water contained are large variety of other tell-tale constituents such as elevated sodium, chloride, nitrate, chromium, and organic solvents — all of which seem to go hand in hand with wells in the Magic Valley that are the most contaminated with radionuclides.

High levels of gross alpha from uranium, plutonium and thorium radioactive wastes, along with hexavalent chromium, have been in INL drinking water as various facilities and have long reached Idaho's Magic Valley downgradient despite claims to the contrary. [24]

Few workers knew of the long-lived radio-iodine, iodine-129, that the Department of Energy was releasing from routine operations, accidents, and even to test the properties of I-129 as a radioactive tracer in the environment over the INL. Iodine-129 in the waste water at the chemical processing plant was rarely monitored for in the aquifer, but it was present, sometimes exceeding what current federal drinking standards are now, at INTEC and Central Facilities, along with enormous levels of tritium in the drinking water.

Technetium-99 in air and aquifer drinking water from fuel separations is also absorbed by the thyroid. The low-functioning thyroid affects the health of the entire body, and a diagnosis may not be quickly obtained. Children and the developing unborn child are particularly harmed by radioactive iodine poisoning the tiny thyroid.

[24] Department of Energy, Environmental Management under DOE-ID, INEEL Subregional Conceptual Model Report, INEEL/EXT-03-01169, Rev. 2, September 2003. p. 4-2. at https://inldigitallibrary.inl.gov/sti/3562854.pdf

Along with elevated tritium and radioactive iodine in both air and drinking water, workers were exposed to elevated levels of alpha particles in water and air. Monitored as “gross alpha” the specific radioisotopes were rarely identified. Likewise, elevated but unidentified “gross beta” was also present in air and INL drinking water. Practices ranged from no monitoring — to repeated monitoring until the average value over a period of time did not exceed recommended concentration limits.

Tritium was disposed of into the Snake River Plain Aquifer from the INL historical operations and many reports focused on tritium in the aquifer. **But not mentioned were long-lived iodine-129, neptunium-237, technetium-99, chlorine-36, carbon-12 and other less mobile radionuclides such as uranium, strontium-90, and cesium-137 that were also injected into the aquifer at INL’s INTEC**, the chemical spent fuel separations facility to recover highly enriched uranium from government reactors. A uniquely important study by the USGS that sampled and analyzed aquifer contamination around INTEC was never reported in a USGS or DOE report. It was not made part of the USGS aquifer bibliography until my request that the study, hidden in a closed-access journal, be added to the USGS bibliography. [25]

Along with radiological contaminants, historical operations at the INL disposed of a multitude of chemical contaminants into the aquifer. The chemical wastes were often used in nuclear fuel reprocessing or other separations processes, then disposed of via deep injection wells, ponds or pits at Idaho Nuclear Technology and Engineering Center (INTEC), ATR Complex (formerly the Test Reactor Area), the Naval Reactors Facility (NRF), [26] and Test Area North (TAN). Chemical contaminants have also reached the aquifer from burial of wastes at the Radioactive Waste Management Complex (RWMC).

Despite over two decades of remediation activities including vapor extraction at the RWMC and TAN for CERCLA cleanup, the levels of chemical contamination in the aquifer at both locations have been increasing. Carbon tetrachloride levels continue to increase at RWMC; 821,000,000 grams disposed of there between 1952 and 1978. Trichloroethylene (TCE) was disposed of via injection well at TAN but the quantity is unknown — but it may have been as much as 35,000 gal. [27] [28]

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[25] T. M. Beasley, P. R. Dixon, and L. J. Mann, “^{99}Tc, ^{236}U, and ^{237}Np in the Snake River Plain Aquifer at the Idaho National Engineering and Environmental Laboratory,” Environmental Science & Technology, 2:3875-3881, 1998.

[26] Department of Energy, “Environmental Management under DOE-ID, INEEL Subregional Conceptual Model Report,” INEEL/EXT—03-01169, Rev. 2, September 2003. p. 3-70, 3-71: S1W Tile Drainfield (1953-55) which “plugged up,” S1W leaching pit (1955-60), and S1W temporary leach pit (1956) were all used for “low-level radioactive waste” which means anything goes, and the downgradient well monitoring reflects that.

[27] Department of Energy, “Environmental Management under DOE-ID, INEEL Subregional Conceptual Model Report,” INEEL/EXT—03-01169, Rev. 2, September 2003. p. 4-2, 4-23 to 4-26.

[28] Department of Energy Idaho Operations Office, *Five-Year Review of CERCLA Response Actions at the Idaho National Laboratory Site,* Fiscal Years 2010-2014, DOE/ID-11513, December 2015.

Tetrachloroethylene, PCE, was disposed of at TAN but the amount is unknown. PCE was also disposed of at RWMC and NRF. Recent detections of PCE north of RWMC are being investigated by the US Geological Survey.

The Advanced Test Reactor Complex, formerly called the Test Reactor Area disposed of unknown levels of contaminants that the CERCLA cleanup has never attempted to investigate. Primarily, this is because the materials involved nuclear fuels and ***weapons material*** separations. **But we do know that over 31,000 lb of hexavalent chromium, widely known to cause cancer, was injected into the aquifer.**

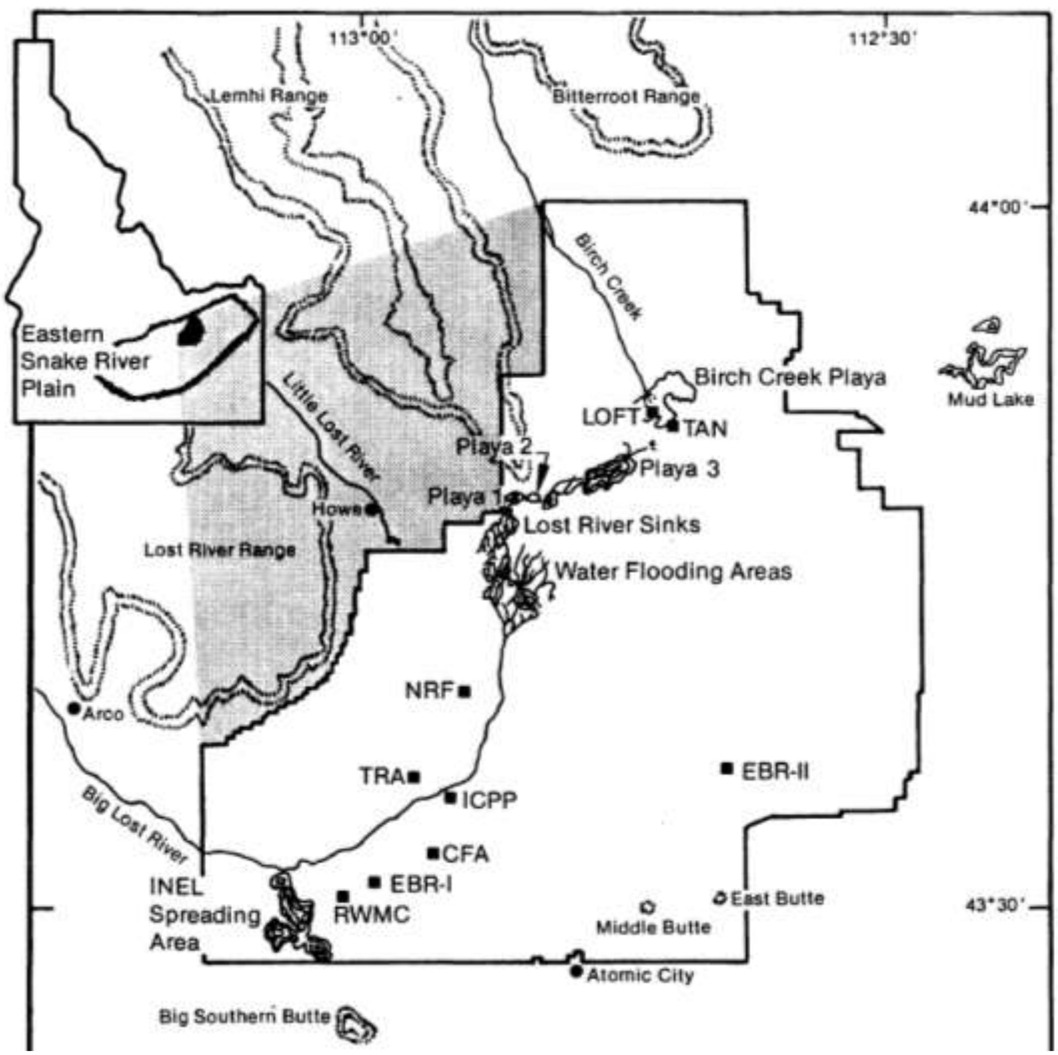

Figure 2. Idaho National Laboratory facilities.

Hexavalent chromium concentration although unstated by the USGS should be below 1 ug/L in the aquifer. Monitoring of groundwater in wells at the southern boundary or south of the INL has found hexavalent chromium at 1 ug/L or higher in wells USGS 90 at 9 ug/L, USGS 108 at 8 ug/L, USGS 11 at 3 ug/L, USGS 14 (also called MV-60/61) at 5 ug/L in report USGS 93-126. [29]

In a summary report for an INL contractor for years 1989 to 1991, hexavalent chromium detections south of INL were summarized as MV-48 at 1 ug/L, MV-49 at 1 ug/L, and MV-59 at 4 ug/L. [30]

You might not be surprised at the amount of chemicals from the INTEC, the chemical processing plant for spent nuclear fuel reprocessing — but actually the Naval Reactors Facility disposed of almost as many chemicals as INTEC. Both INTEC and NRF are upgradient of the recently found PCE contamination. See Figure 2 for the location of various INL facilities.

Once a contaminant is in the aquifer, it flows downgradient, generally to the southwest of the INL. So even if a well at the INL shows a decrease in contamination concentrations, that's not the big picture unless the half life of the material has significantly reduced what flows in the aquifer downgradient. Also, soil may slow the migration of contaminants buried in waste or in percolation ponds — but once that contamination is in the aquifer, it flows downgradient, generally flowing deeper as it flows from the source of the contamination.

Despite the chemical disposal via injection wells, percolation ponds and waste burial, commencing in the early 1950s, the US Geological Survey did not monitor **chemical contamination** until the late 1980s. In the reports that the US Geological Survey issued, the public was always assured that they were keeping a watchful eye, rigorously monitoring the aquifer. They were monitoring the aquifer but in ways meant to keep the Department of Energy, formerly the Atomic Energy Commission, able to keep polluting and keeping the public from understanding what was actually happening.

The USGS was intimately involved in hiding information pertaining to nuclear weapons fallout, weapons material separation techniques, and various chemical and radionuclide contamination. Instead of comprehensive disclosure, the USGS choose to discuss tritium and a few other radioisotopes with relatively short half life. The USGS choose to avoid discussing radionuclide contamination of longer-lived contamination. And the USGS choose to word its reports in ways to hide the fact that workers at INL were drinking highly contaminated water for decades.

The chemical soup from INL waste water disposal has been flowing downgradient for decades. Let's take a look at some of these chemicals and what facilities they came from — then the detection of various chemicals downgradient will take on a whole new meaning that the USGS

[29] Liszewski, M.J. and Mann, L.J., "Concentrations of 23 Trace Elements in Ground Water and Surface Water at and near the Idaho National Engineering Laboratory, Idaho, 1988-91," US Geological Survey Report 93-126, 1993.

[30] Golder Associates, for EG&G Idaho, "Assessment of Trends in Groundwater Quality at the Idaho National Engineering Laboratory," 933-1151, October 29, 1993..

has downplayed. Because so many reports present only a fragmented look at the chemical contaminants, a list of chemical contaminants most prevalent at the INL from various CERLCA cleanup, USGS and other reports is provided in Table 2. [31] [32] [33] [34] [35] [36]

Table 2. Facilities that disposed of chemical contaminants at the Idaho National Laboratory that have been **found in the aquifer in significant concentrations**.[a]

Chemical	RWMC	TAN[d]	INTEC	TRA[b]	NRF[c]
Carbon tetrachloride	G				
Chloroform	G		G		G
Dichloro-difluoromethane	G	G			
Methylene chloride	G		G		x
1,1,-Dichloroethane		G	G		
Cis-1,2-Dichloroethene		G			
Trans-1,2,-Dichloroethene		G			
Tetrachloroethylene, PCE	G	G			G
Trichloroethylene, TCE	G	G	G		G
1,1,1-Trichloroethane	G	G	G	G	G
Toluene	G	G	G	G	G
Hexavalent chromium	Note e	Note e	Note e	G	Note e

Table notes:
a. The facilities are the Radioactive Waste Management Complex (RWMC), Test Area North (TAN) and vicinity, Idaho Nuclear Technology and Engineering Center (INTEC) — formerly the Chemical Processing Plant and vicinity including Central Facilities Area that received contaminated drinking water from INTEC, Test Reactor Area, now called the Advanced Test Reactor Complex, and the Naval Reactors Facility (NRF).
b. Acrylonitrile was found in soil and waste water disposal entrances at TRA. The Department of Energy patents acrylonitrile in 1989, see http://www.aquafoam.com/patents/CA4832881.pdf . The "reporting level" for acrylonitrile has been set at a very high level, for years 20 ug/L when other chemicals were at reporting threshold levels of 0.2 ug/L. The reason for this is unknown.
c. Aroclor-1254, Aroclor-1260, Bis-2-Ethylhexl-phthalate, Din-Octylphalate, Di-n-Octylphalate and benzene were found is disposal ditch soil at NRF. The "reporting level" for Acrolein compounds (which include Aroclor) is set at 20 ug/L when other chemicals were at reporting threshold levels of 0.2 ug/L. The reason for this is unknown.
d. At Test Area North, Trans-1,2,Dichloroethene levels of 22,000 microgram per liter (ug/L) and Trichloroethylene of 35,000 ug/L were measured in 1987. Typical limits for drinking water are 5 ug/L. Source USGS report: 87-766.
e. USGS Report 93-126 found elevated hexavalent chromium at TAN and NRF and the TRA hexavalent chromium plume has spread to INTEC and RWMC as well as south of INL.

[31] Department of Energy, "Environmental Management under DOE-ID, INEEL Subregional Conceptual Model Report," INEEL/EXT—03-01169, Rev. 2, September 2003. p. 4-2, 4-23 to 4-26.

[32] Greene, M.R., Tucker, B.J., "Purgeable Organic Compounds in water at or near the Idaho National Engineering Laboratory, Idaho, 1992-95," US Geological Survey Report 98-51, June 1998.

[33] Liszewski, M.J. and Mann, L.J., Purgeable organic compounds in ground water at the Idaho National Engineering Laboratory, Idaho – 1990 and 1991," US Geological Survey Report 92-174 (DOE/ID-22104), 1992.

[34] Mann, L.J.and Knobel, L.L., "Purgeable organic compounds in ground water at the Idaho National Engineering Laboratory, Idaho ," US Geological Survey Report 87-766, December 1987. https://pubs.usgs.gov/of/1987/0766/report.pdf

[35] See the Naval Reactor Facility final environmental impact statement at www.ecfrecapitalization.us and the summary at http://www.ecfrecapitalization.us/EIS-0453-FEIS_Summary.pdf See Chapter 3.

[36] Till, J.E. et al., Radiological Assessment Corporation, for the Centers for Disease Control, "Final Report – The Feasibility of Performing a Chemical Dose Reconstruction Study at the INEEL," RAC Report No. 4-CDC-Task Order 1-1999-Final, September 1999. https://www.cdc.gov/nceh/radiation/ineel/taskorder1report.pdf

In fact, even as chemical contamination exceeds drinking water standards at the waste burial ground, now called the Radioactive Waste Management Complex and at Test Area North, and the aquifer in these areas is growing increasingly contaminated despite years of vapor vacuum extraction of the organic solvents, **the USGS is discontinuing monitoring of total organic carbon.**[37]

For a few years starting in 1987, the USGS performed analyses of numerous chemical constituents in many wells. The problem, however, is that inexplicably high reporting levels are used for some chemicals like Acrolein and Acrylonitrile that may have been used extensively at TRA and NRF for fuels separations. There is no explanation of very high levels of organic carbon. Toluene and xylene found in limited monitoring prior to 1987 appear to be a rough cut at identifying the chemical contaminations and may not be fully representative of chemicals in the aquifer.

The State of Idaho public drinking water monitoring program that began in the late 1980s was still not mature in the early 1990s. Initially the state program required both chemical and radiological monitoring of drinking water at the INL. But at the request of the Department of Energy, the state ceased collecting radionuclide drinking water data (tritium, gross alpha, and gross beta) from the INL drinking water wells. The legal basis is that the INL drinking water wells are non-transient non-community wells – no one lives there. But this loop hole was intended to hold down costs for monitoring campgrounds, for example, should not be used as an excuse to withhold from public view the contamination levels of chronically radiologically contaminated nuclear sites.

Even though the drinking water maximum contaminant level (MCL) for tritium in water is an industry-friendly 20,000 pCi/L, people concerned with humans having healthy babies consider 100 pCi/L to be about the maximum that pregnant women should be drinking because of the damage to DNA and concern for birth defects, as California public health goals attest. See federal drinking water maximum contaminant levels for various radionuclides and chemicals at the end of this report.

[37] See DOE/ID-22232, page 8.

A Quick Summary of Some Key Radionuclides

Tritium (H-3), half life of 12.3 years, is a weak beta emitter and cannot be detected by most radiation detectors. It's spread cannot be filtered from stack emissions or groundwater. The detection usually requires concentration of it and long counting times in a laboratory. It spreads throughout the body. However, it can also be incorporated into DNA. It is particular harmful for the unborn developing child.

Iodine-131, half life of 8 days, beta and gamma emitter, was prevalent in INL fuel melt releases, and prevalent from INTEC prior to effective filtering. It was also released in large amounts from the Nevada Test Site. It contaminates grass, and when eaten by cows enters milk that is ingested by humans. It accumulates in the thyroid. It is known to cause thyroid cancer, and compromise the immune system.

Iodine-129, half life 16 million years, both beta and gamma emitter, was released by the INL and even dumped from airplanes to conduct experiment tracer tests. It accumulates in the thyroid.

Cesium-37, half life of 30 years, beta emitter, is a fission product. It bioaccumulates in plants. It mimics potassium in the body. Studies of Chernobyl indicate that it is associated with increased risk of blood disorders, cardiac arrhythmias, autoimmune diseases, neuromuscular diseases, reproductive problems, and cancer.

Strontium-90, half life of 29.1 years, beta emitter, is a fission product. It also bioaccumulates in plants. It is a bone seeker.

Plutonium-238 and -239, half life of 88 yr and 24,000 years but does not decay to a stable isotope so radioactive decay progeny follow its decay. Both are alpha emitters and weak beta emitters. Pu-238 is also a weak gamma emitter. Plutonium is associated with cardiovascular disease, leukemia, lung cancer, breast cancer, childhood cancers, infant mortality and trans-generational mutations. Pu-238 ultimately decays to Lead-206. Note that Neptunium-239 decays to Pu-2239. Pu-239 decays to the U-235 decay chain and ultimately to Lead-207.

Americium-241, half life of 432 yr but does not decay to a stable isotope so radioactive decay progeny follow its decay and for thousands of years. Am-241 has a gamma ray that can be detected and is used to infer plutonium in lung counts when it would be impossible to detect alpha particles. Faster clearance of americium-241 from the lung than plutonium would lead to underestimation of plutonium in lung count results. Americium builds up significantly in plutonium from Pu-241 in just a few years. To purify stored plutonium, americium would be separated from the plutonium, creating highly concentrated americium-241, with vast amounts disposed of at INL's RWMC from the Rocky Flats weapons plant. Am-241 decays to Neptunium-237 which decays to U-233 and ultimately to Lead-209.

Uranium-238, half life of 4.5 billion years but does not decay to a stable isotope; many radioactive decay progeny follow its decay. Primarily an alpha emitter but also has a weak beta and gamma emission. Natural uranium contains decay product uranium-234 and also U-235 by small fraction by weight. However U-234 and U-235 in natural concentrations roughly double to radioactivity of U-238 that is reduced to some degree (depleted) in U-234 and U-235. Uranium is associated with cancer, miscarriage, still births, childhood cancers, birth defects, infertility, brain disorders, kidney disease, and trans-generational mutations. Natural uranium exists in small concentrations and fairly soluble forms. Uranium left over from the enrichment process to extract U-235 is called depleted uranium and is mostly uranium-238. Uranium that is chemically altered may be more or less soluble. Spent nuclear fuel is usually over 90 percent unfissioned uranium. Fuel made of higher uranium-235 enrichment may have higher burnup, and will accumulate more fission products as the fuel is fissioned in a reactor. Reactor fuel melt accidents always release uranium as does atomic bomb use or testing. Even the plutonium bombs use U-238 blankets and so while the uranium and plutonium mixtures may vary for different bomb designs, typically uranium also is included in weapons testing fallout even though very little monitoring or mention of it is made. U-238 ultimately decays to Lead-206. U-235 ultimately decays to Lead-207. [38]

Within four to six months after being discarded from a uranium enrichment facility, depleted uranium is composed mostly of U-238, Th-234, Pa-234m, Pa-234, and U-234 in equilibrium proportions. The thorium-234 and Protactinium of the first two decay products account for most of the alpha, beta, and small amounts of gamma radioactivity of the mixture.

Rosalie Bertell writes: “One milligram of pure U-238 undergoes 12.4 disintegrations every second, imparting an alpha particle with an energy between 4.15 and 2.4 MeV (million electron volts) in random directions. It requires only 6 to 10 eV to break the nuclear DNA strand in a cell. In one day, 1 milligram of pure U-238 would release 1,071,000 alpha particles, into the organ or tissue where it was lodged.” [39]

Uranium-233, half life160,000 years, is a man-made uranium isotope that is usable as weapons material. It was used is a few weapons tests and experimented with at the INL. It ultimately decays to lead-209.

Thorium-232, half life 14 billion years. There are various isotopes of thorium. Natural thorium-232 decays to Th-228. When Th-232 or Th-228 is detected but should not naturally be present in the soil or water, it is indicative of special research using thorium, often to breed U-233, a weapons usable material. Uranium-236 can be created by neutron absorption of U-235 in a reactor; U-236 decays to Th-232. Th-232, Th-228 and U-233 are found in the aquifer and soil

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[38] See our factsheet with uranium and thorium decay series in “Radionuclides in Groundwater Fact Sheet” at www.environmental-defense-institute.org

[39] Rosalie Bertell, International Journal of Health Services, “Depleted Uranium: All the Questions About DU and Gulf War Syndrome Are Not Yet Answered,” 2006. https://ntp.niehs.nih.gov/ntp/roc/nominations/2012/publiccomm/bertellattachmentohw.pdf

at the INL and are not, I repeat, are not naturally occurring but is the result of research and dumping of these radioactive materials. The health effects probably resemble those of uranium. Note that Th-234 and Th-230 are decay products of U-238. Thorium-231 and Th-227 are decay products of U-235. These are also released from INL research and disposal practices. Th-232 ultimately decays to Lead-208.

Thorium-232 was used to breed fissile weapons material uranium-233. There were many U-233 programs at the Idaho site at the Naval Reactors Facility, Test Reactor Area (now the ATR Complex), ANL-W (now the Materials and Fuels Complex), and the Radioactive Waste Management Complex. Uranium-233, analogous to fissile weapons material plutonium-239, is bred from thorium fuel combined with highly enriched uranium-235 seed fuel. The Department of Energy dumped anything and everything into the Snake River Plain aquifer in the 1950s through 1970s. Direct disposal to the aquifer of thorium and uranium materials following examination, separations or reprocessing operations at the INL resulted in largely unmonitored or under-monitored contamination of the aquifer until drinking water programs began in the late 1980s and early 1990s in the State of Idaho.

Many radioactive and chemical wastes resulting from DOE facilities at the Idaho National Laboratory were not identified by the USGS aquifer monitoring when CERCLA cleanup investigations commenced —see the CERCLA cleanup report and others at the administrative record. [40] Along with plutonium and many uranium isotopes, the INL CERLCA cleanup found contaminants of concern, meaning that the quantities involved were significant to human health, that included thorium isotopes, uranium-233 fissile material bred from thorium, and europium-152, a contaminant of U-233 production. Many of these contaminants were rarely if ever reported by the USGS as having been disposed of at INL prior to CERCLA cleanup investigations.

Why Radiation Protection Standards Aren't Protective

Radiation protection standards were created by people working on behalf of the nuclear weapons industry and nuclear energy industry. Although some of these people had some training in biology, by and large they were loyal to their employers and their nuclear interests. People loyal to human health interests if involved have typically been expelled or discredited, like John W. Gofman, MD and Alice Stewart, MD. [41] [42]

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[40] See INL CERCLA Cleanup Administrative Record at https://ar.icp.doe.gov and See one report for an idea of contaminants in Department of Energy Idaho Operations Office, "Final Removal Action Report for CPP-601, CPP-602, CPP-627, CPP-630, and CPP-640," DOE/ID-11453, February 2012. See Table 3, p. 19 and 20. *https://ar.icp.doe.gov/images/pdf/201202/2012022800768BRU.pdf*

[41] Books by John W. Gofman, M.D., Ph.D.:*Radiation and Human Health*, Sierra Club Books, 1981; *Radiation-Induced Cancer from Low Dose Exposure: An Independent Analysis*, 1990; *Preventing Breast Cancer: The Story of a Major, Proven, Preventable Cause of this Disease*, Committee for Nuclear Responsibility, Inc., 1996.

If the organizations that created radiation protection standards had more interest in protecting human life than they have in protecting the health of the nuclear weapons and nuclear industry, they would take an interest in the strong, compelling and diverse human epidemiological evidence that radiation is more harmful than official estimates portray, wouldn't they? Decades would not pass by without any action by them to improve radiation worker safety and public safety, as has been the case.

The military wanted to know what dose troops could survive and still function for a few weeks. They learned the acute radiation dose that would kill half of those exposed within a few weeks. Radiation was observed to be associated with cancer and leukemia. Much emphasis has been placed on observing cancer and leukemia rates and it is these disease rates that take up much of the radiation health effects publications.

But sometimes the obvious is not so obvious. Statistics concerning the women who painted radium dial watches and would touch the paint brush to their lips, have been noted by some radiation researchers to have had fewer cancer deaths. They are aiming to minimize the appearance of adverse radiation health effects. But many of these women exposed to radium, an alpha emitter, died young and of unstated causes. Actually fewer of them lived long enough to get cancer. Yet, there are people who will cite with great fervor the reduced cancer deaths of women exposed to radium.

It is appears to still be repeated, though decades after proven false, that no radiation harm can be detected for radiation doses below 10 rem. This is still being taught to Health Physics students, despite being untrue. **There has long been assembled medical radiation cases of doses far below 10 rem that showed elevated disease caused by the low dose exposures**. John W. Gofman, MD, once the lead researcher for the Department of Energy's radiation research program—until he said the radiation harm was higher than currently recognized and was sacked—assembled many such medical cases of very low doses causing health harm. The evidence has continued to mount.

Since the BEIR VII report, we know that women are twice as vulnerable to radiation-induced illness than men, and children more vulnerable than adults, the unborn being the most vulnerable. Why don't they tell this to female radiation workers? In the US, allowable radiation limits set for pregnant workers are still not adequately protective. I strongly encourage female radiation workers who are or who may become pregnant to read "The Woman Who Knew Too Much — Alice Stewart and the Secrets of Radiation." And what men don't know is that their unmonitored or otherwise ignored plutonium or uranium ingestion dose may greatly increase the chance of birth defects in their children.

Ian Goddard explains the "linear no-threshold" radiation health risk model and compares it to epidemiology results since 2006 in a video he created. He gave EDI permission to share it on our

[42] Gayle Greene, "The Woman Who Knew Too Much – Alice Stewart and the Secrets of Radiation," The University of Michigan Press, 2003.

website. Please find it on our Radiation health page. [43] By reviewing recent human health epidemiology of mixed ages (adults and children) and of children only, Ian explains why the linear no-threshold model is still appropriate. He also shows that human epidemiology results show harm from radiation exposure far below 10 rem lifetime exposures.

The 2006 Biological Effects of Ionizing Radiation, or BEIR VII report found that the current International Commission on Radiological Protection (ICRP) model underestimates cancer risk. The ICRP model has been found to underestimate the risk of cancer by at least a factor of 2.

As Ian Goddard points out in a related video that both the ICRP and BEIR VII radiation risk levels underestimate the health risk of low doses accumulated over time as studied by a meta analysis of radiation workers in many countries. [44] The 2009 study by Jacob showed that while there are problems with accuracy of dose estimates, doses accumulated slowly and to a level of about 10 rem total, were not less harmful than doses accumulated all at once, as the victims of the atomic bombing of Japan received. The underpinnings of the ICRP model used for nuclear workers and medical radiation exposures are based on the study of Japan's atomic bomb survivors. However, the dose reduction factors assumed in these models are based on animal studies that are not supported by human epidemiology. The slow dose rate reduction factor taken by ICRP (of 2) and by BEIR VII (of 1.5) based on animal studies are simply not valid for humans and are one reason these models under-predict radiation harm.

The Department of Energy still uses the outdated and long proven to underestimate risk ICRP model for accident risk assessment and for its radiation protection of workers. Past studies conducted by or for the Department of Energy to assess the harm of its fallout on communities has been based on ICRP models of various editions. The Department of Energy's ignoring the bad news that radiation health effects are worse at slowly accumulated doses far less than half of its 5 rem per year standard and at lifetime doses of about 10 rem continues to harm workers. The harm from radioactive fallout from the Department of Energy's past radiological releases in Idaho, New Mexico and Nevada has been argued based on ICRP models that underestimated to harm to embryos and children, especially female children. And the evaluation of probability of causation for former energy workers in order to qualify for compensation also use the outdated ICRP models that under predict harm by at least a factor of two for external radiation exposure as it relates to the risk of developing a solid cancer (not leukemia which is a higher, non-linear risk).

A dose conversion chart comparing rem and milli-rem, commonly used by radiation workers to international radiation units of Sievert is provided in Table 3.

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[43] http://www.environmental-defense-institute.org/radhealth.html

[44] P. Jacob et al., Occup Environ Med, "Is cancer risk of radiation workers larger than expected?" 2009;66:789-796 http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2776242/pdf/BWC-66-12-0789.pdf

Table 3. A radiation dose unit conversion chart.

500 rem =	500,000 mrem =	5 Sv =	5000 mSv	Half of adults exposed to this acute dose would die within 30 days
100 rem =	100,000 mrem =	1 Sv =	1000 mSv	
50 rem =	50,000 mrem =	0.5 Sv =	500 mSv	People exposed to this acute dose would likely have radiation illness symptoms. Increased cancer risk would occur whether acute exposure or fractionated doses
10 rem =	10,000 mrem =	0.1 Sv =	100 mSv	This is typically the threshold for what is considered a “low dose.” Adults exposed to this acute dose do not show symptoms but have increased cancer risk even if the exposure is from small fractionated doses
1 rem =	1000 mrem =	0.01 Sv =	10 mSv	**Note that the international radiation worker dose limit is 2 rem/yr but in the US remains 5 rem/yr probably so they can fry workers when it will save money in repairing nuclear plants.**
0.1 rem =	100 mrem =	0.001 Sv =	1 mSv	The public is allowed 100 mrem/yr from the nuclear industry, but epidemiology is finding harm from doses accumulated at this low dose rate

1000 millirem (mrem) = 1 rem; 1000 millisieverts (mSv) = 1 Sv.

The intake of radionuclides of a particular radioisotope is measured in disintegrations per second, also known as becquerel (bq). This may also be expressed in curies, where there are 3.7E10 becquerel in 1 curie. It can be help to know that 1 nanoCurie (nCi) is 1.0E-9 curies; and one picocurie (pCi) is 1.0E-12 curies.

Note that 1 disintegration/second = 60 disintegration/minute (dpm) = 27 pCi.

For each radioisotope, the grams of it can be determined if the curie amount is known. For example, 1 nCi Pu-239 is equal to 16.3 nanograms of Pu-239.

If the Pu-239 inhalation dose conversion factor of 9.0E-5 Sv/bq were used, 15.0 nCi or 555.5 bq of Pu-239 would result in a whole body committed effective dose of 5 rem or 50 mSv.

Internal Alpha Emitters

The predecessor of the Department of Energy, the Atomic Energy Commission, knew that alpha emitters could be a significant health hazard. They were so keen to set standards so as to protect workers but be able to retain contaminated workers as long as possible that they paid medical doctors to inject suitable patients with plutonium and send their urine back for analysis. The doctors were to select dying patients who, without consent, were to be injected with plutonium and their urine collected for the purpose of evaluating plutonium excretion rates from the body.

The concept of predicting plutonium intake from the amount of plutonium excreted in urine made sense in concept, but it has not been a reliable method of plutonium intake.

This unethical nightmarish behavior of injecting medical patients with plutonium may have been justifiable during wartime. But this sort of behavior continued years after WWII ended. And when the Secretary of Energy Hazel O'Leary learned of it, she exposed it.

With Hazel O'Leary's administration, the "Human Radiation Experiments" documents were borne. Although many of these documents are still held out of public view despite so-called transparency, she is still to be credited with shining some light on very dark actions by the Department of Energy (or predecessor the Atomic Energy Commission).

At LANL they learned that the urine sample concentrations were smaller if the workers were required to enter a hospital instead of stay at home, and don clean clothes and sheets before giving the urine samples. Although unstated, the implication is that these workers gave urine of higher plutonium contamination if remaining in their own contaminated homes and linens.

The workers at the INL contaminated with plutonium and uranium at the 2011 ZPPR accident were given the opportunity to be spoken to by DOE radiation researcher Antonne Brooks. Professor Brooks told them that their doses were low because back in the day, he knew workers who were peeing plutonium in their urine. The ZPPR workers responded that they were peeing plutonium in their urine, based on bioassay results (and were for months after the exposure). Dr. Brooks appeared unaware that these workers were peeing plutonium. But he continued to lecture them on the insignificance of their dose, despite his personally not having reviewed the evidence. This lecture was made as a token to satisfy the promise to provide medical advice to the workers contaminated with plutonium from the accident.

Some of these workers were initially told their radiation doses were significant and given chelation therapy. Then the next day were told that further medical evaluations were not needed based on radiation dose estimates that were not completed for another 10 months. The workers were asked to sign documents stating their radiation dose had been explained, only to have no access to their dose estimation documents — at least, not without completing Freedom of Information Act requests and waiting many more months after waiting 10 months for their radiation dose estimates to be finalized.

It has become very difficult for me to trust any analysis conducted by the Department of Energy or by its contractors. The ZPPR accident resulted in lost logbooks detailing contamination levels in decays per minute detected, destroyed urine samples that might have shown rapid americium-241 clearance, ignored lung count results that would have exceeded federal dose limits for whole body and organ dose, and numerous other irregular and unethical behaviors.

And this didn't happen during the Cold War. It happened as the result of unjustifiable cost saving attempts that had removed proper radiation monitoring equipment and had resulted in hasty improper approval of inadequate work procedures, inadequate training, and incorrect management actions — all resulting in workers who were performed tasks as required of them getting unhealthy doses of plutonium and uranium. The reality of compromised ZPPR fuel plates being an anticipated event was treated as though it was still thought to be an extremely unlikely event. Management directed that the plastic wrapping on the plates be opened — and this exposed workers to airborne contamination that would only be detected after minutes of inhalation and contamination had occurred — enough to exceed federal limits for some workers. Later, the managers most at fault would blame the workers for the accident.

Actively Ignoring the Uranium

The 2011 ZPPR accident was explained in terms of the fuel content of the plates; their composition of uranium-238 and plutonium, and the buildup over time of americium. It was explained how the International Commission on Radiation Protection (ICRP) dose conversion factors showed that the uranium dose could be ignored. The dose conversion factors contain the derived statistics for the risk of cancer.

The problem is that the other effects of uranium, which was by mass the largest intake during the ZPPR accident, in reality, have the potential for many adverse health effects in addition to the increased risk of cancer. For one thing, the solubility of the uranium and the chemical structure could greatly affect the physical clearance and the health risk.

The nuclear industry has long downplayed the health effects of uranium. The effects of "depleted uranium" which is uranium-238 with lower concentrations of uranium-235 have now been exemplified in Gulf War veterans.

I had discounted what I had read about depleted uranium contamination of Gulf War veterans as not being applicable to ZPPR workers because some accounts said the Gulf War DU was in the form of nano-particles (1.0E-9 meters in diameter). But Gulf War DU might be only micro-AMAD sized particles, similar to the ZPPR contamination. The DOE's contractor for ZPPR had taken great pains to not estimate the size of the ZPPR particles despite having taken extensive research to support the conclusion that the contamination was not moderately insoluble, but was more insoluble than M class. The DOE's contractor took great pains to avoid determining the full extent of insolubility — which if they had, could have resulted in determining that the contamination was not just S class for highly insoluble — they might have proven that it was Super S class, highly insoluble and likely to be retained in the lungs much longer. But they stopped the research in order to avoid determining whether the material was Super S class.

A study conducted in France of two incidents involving internal exposure by inhalation of transuranic compounds found that **dose estimates using the ICRP model could range from an insignificant 10 mrem (or 0.1 mSv) to a very significant dose of 30 rem** (30,000 mrem or 300 mSv). [45]

The methods for assessing internal dose usually involve collection and evaluation of bioassay samples (urine and fecal samples). But the internal dose estimate based on urine was much higher than the dose based on the radioactive excretion rate indicated by fecal samples. The conclusion made by these French analysts was that **a reliable estimate of radiation dose could not be made based on the accepted model**, the International Commission on Radiological Protection (ICRP) model. The ICRP model is used by the Department of Energy and its contractors to estimate radiation dose. **The biokinetics of the ICRP model do not reflect what is happening in the body and neither the urine or fecal excretion followed ICRP model behavior.**

In addition to the experience in France of inhalation events of oxide forms and other forms of plutonium that were found to not be represented by the ICRP model based on the predicted urine or fecal excretion, **the autopsy of radiation workers in the US from the Rocky Flats weapons plant found the ICRP models to underestimate the plutonium that would be retained in the lungs.** Now even NIOSH acknowledges that Super S Class, highly insoluble material is retained longer in the lungs than the official models predict. But despite knowing the inadequacy of the ICRP model, the Department of Energy and its contractors use it and typically ignore Super S class, which could raise the radiation dose. Analysts have basically unlimited license fiddle with the urine, fecal and other indications of intake in any manner they choose. And they will choose to fiddle with these until their mathematical models produce the low radiation dose they desire.

The urine sample of a ZPPR worker was twice that of a worker in a French accident at day 2 and the fecal contamination of a ZPPR worker was 770 times that of a worker in a French accident on day 1. The accidents both involved high levels of americium-241 and various plutonium isotopes. The ZPPR worker was assigned an estimated dose just above 100 mrem and the French worker was acknowledged to have a dose was unknown because the model resulted in a dose anywhere between 10 mrem and 30 rem depending on how modeling assumptions were made, because of discrepancies in the ICRP model.

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[45] "Assessing internal exposure in the absence of an appropriate model: two cases involving an incidental inhalation of transuranic elements" by Nicolas Blanchin et al. (circa 2006) http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=8804577

Avoiding Medical Reality-based Monitoring

There are ways to monitor the blood of workers exposed to a large dose of radiation. Blood tests of white blood cell counts, particularly of monocyte depletion can be conducted. "The monocyte stem cells in bone marrow are known to be among the most radiosensitive cells. Their depletion can lead to both iron deficient anemia, since they recycle heme from discarded red blood cells, and to depressed cellular immune system, since monocytes activate the lymphocyte immune system after they detect foreign bodies." [46]

Some of the ZPPR workers were told the night of the accident that their radiation doses were very high and that blood tests would be needed. But by Day 2 after the event, the blood tests were discontinued on the basis of quickly drafted and speculative dose estimates. Even if the estimated radiation doses were thought to be lower than initially thought, there are medical tests that could have been continued to confirm the highly uncertain dose estimates that are reliant on a known to be inadequate ICRP model.

If the DOE or its contractor actually cared about worker health, it would conduct blood tests to confirm that the estimated doses are actually low. The DOE avoids tests that could accurately show the extent of internal alpha contamination, such as FISH tests that could DNA breaks in a sample and compare to result to the normal number of DNA breaks. Instead, mathematic estimates are relied upon that may have little to do with the actual dose workers have received. For these workers to obtain FISH tests will be expensive. But these tests may be able to show the extent of internal alpha contamination even years after the event because incorrectly repaired DNA replicate.

By using multicolor banding fluorescence in situ hybridization (mBAND FISH), past exposure to high-LET radiation (such as alpha radiation from plutonium) can be detected by blood tests years after the intake. See the 2004 report that compared damage to chromosomes in Russian Mayak plant plutonium workers to workers with only gamma radiation exposure. [47]

To read the report it is useful to keep in mind these definitions:

- **Intrachromosomal aberrations** mean aberrations occurring within a single chromosome.
- **Interchromosomal aberrations** are chromosome breaks that are distributed relatively uniformly across many or all chromosomes.

[46] Rosalie Bertell, "Gulf War Veterans and Depleted Uranium," Laka Foundation, May 1999. http://www.ccnr.org/du_hague.html

[47] C. R. Mitchell, T. V. Azizova, et al., "Stable Intrachromosomal Biomarkers of Past Exposure to Densely Ionizing Radiation in Several Chromosomes of Exposed Individuals," 2004. http://www.columbia.edu/~djb3/papers/radres10.pdf

The 2004 report states, “a large yield of intrachromosomal aberrations was observed in both chromosomes of the individuals exposed to high doses of plutonium, whereas there was no significant increased over the (low) background control rate in the population who were exposed to high doses of gamma rays.”

But as you will learn more about the oxidative stress caused by ionizing radiation, you might begin to wonder why more testing of oxidative stress wasn’t performed. Or why nutritional support has never been recommended for INL workers known to have significant exposures. **By the 1950s, researchers had identified that oxidative stress was strongly induced by ionizing radiation.** [48]

Understanding How Radiation and Heavy Metals Upset Cellular Processes

Chronic exposure to relatively low levels of ionizing radiation does more than damage DNA, it damages cells, including the cellular membranes by causing oxidative stress. It is important to understand this because of the role that chronic oxidative stress plays in the progression of degenerative diseases. Ionizing radiation does not just cause cancer; it does not just cause DNA damage and genetic effects — ionizing radiation also causes many other diseases from heart disease to neurological diseases.

In addition to normal living that causes free radicals, ionizing radiation can vastly increase free radicals as can toxic chemicals. And workers at the Idaho National Laboratory since 1949 have been exposed to both ionizing radiation and various chemicals such as carbon tetrachloride and other chemical solvents and various other chemicals.

The reactive oxygen species resulting from ionizing radiation include superoxide O^-_2; hydroxyl OH, and hydrogen peroxide radical H_2O_2. Antioxidant enzymes and individual antioxidants can become depleted if your levels of oxidative stress has been elevated or your diet has been nutritionally inadequate for the demand.

You may know that ionizing radiation delivers far more energy than is needed to rip electrons off of molecules, creating electrically charged ions. The amount of energy from radioactive decays can be several thousand electron volts (MeV), far more than the small amount of energy that is normally used within the cells normal chemical processes, commonly 0.5 to 2 electron volts. [49] You may recognize the term “free radicals” and the need to combat excessive free

[48] Editor Chuang Chin Chiueh, *Reactive Oxygen Species From Radiation to Molecular Biology – A Festschrift in Honor of Daniel L. Gilbert*, Annals of the New York Academy of Sciences, 2000. (See p. 28 J. B. Mitchell et al., “Radiation, Radicals, and Images.”

[49] John W. Gofman, M.D., Ph.D., *Radiation and Human Health*, Sierra Club Books, 1981

radicals with antioxidants. Your body is mostly made of water. Ionizing radiation absorbed by water will result in the production of free radicals that in turn can attack other critical molecules.

For a scientific discussion of radiation and its generation of reactive oxygen species, read this 2012 publication "Ionizing radiation-induced metabolic oxidative stress and prolonged cell injury." [50] For a discussion about what to do to help your body cope with excessive free radicals, I suggest you read this book: "Fukushima Meltdown & Modern Radiation: Protecting Ourselves and Our Future Generations" by John W. Apsley, II. [51]

Ionizing radiation rips electrons off of the molecules that make up our cells, damaging the cells. Ionizing radiation increases the levels of free radicals. A free radical is matter with at least one unpaired electron. Oxygen, for example, can be in a stable diradical O_2 form that has no electrical charge. But when oxygen is in the superoxide form O_2^- , it is a negatively charged anion. Two other prominent reactive oxygen species are hydrogen peroxide, H_2O_2 and hydroxyl, OH-. It thus becomes crucial to understand how to support your body's defenses with antioxidant enzyme systems such as superoxide dismutase, and with non-enzyme antioxidants. See Table 4.

[50] Edouard I. Azzam et al., *Cancer Letter*, "Ionizing radiation-induced metabolic oxidative stress and prolonged cell injury" 2012 December. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3980444/

[51] John W. Apsley, II, MD(E), ND, DC, *Fukushima Meltdown & Modern Radiation: Protecting Ourselves and Our Future Generations*, Temet Nosce Publications, 2011. ISBN 978-0-945704-97-2

Table 4. The five antioxidant enzyme systems.

Enzyme	Free Radical Acted Upon	Action	Supportive Nutrients
Superoxide dismutase (SOD)	Superoxide O_2^-	Cu/Zn SOD neutralizes free radicals in the cytoplasm of cells. Mn SOD neutralizes free radicals in the mitochondria of cells.	Manganese SOD, and Copper/Zinc SOD can become depleted. Broccoli, Brussels sprouts, and other greens. CoQ10.
Catalase	Hydrogen peroxide H_2O_2	Catalase is an enzyme needed to decompose hydrogen peroxide into water and oxygen.	Whey and other foods rich in cystine and cysteine.
Glutathione-peroxidase	Lipid peroxide and hydrogen peroxide	Glutathione is needed for essential detoxification processes including both Phase 1 and Phase II detoxification Heart disease, premature aging and other illnesses arise from lack of glutathione.	Glutathione can become depleted as the body copes with radiation exposure, causing a host of chronic illnesses. Glutathione is made up of N-acetyl-cysteine, glycine, and glutamic acid. NAC combined with vitamin C is supportive of glutathione levels.
Methionine reductase	Hydroxyl OH-	Methionine neutralizes hydroxyl radicals which damage any tissue type.	Selenium, folic acid, B-12 and methionine, Melatonin is particularly important for mopping up hydroxyl. Methione can become depleted.
Thioredoxin reductase		Thio means the presence of sulfur. Thioredoxin teams with glutathione to quench reactive oxygen species. Thioredoxin is considered very important to prevent	Cabbage, wasabi. Also curcumin.

		"Chernobyl Heart" or cardiac hypertrophy.	

Source: Fukushima Meltdown & Modern Radiation: Protecting Ourselves and Our Future Generations by John W. Apsley, II MD(E), ND, DC.

Glutathione protects against oxidative damage. Enzyme superoxide dismutase (SOD) convert superoxide into hydrogen peroxide, allowing the enzyme catalase to convert the hydrogen peroxide into water and stable oxygen. Cellular repair mechanisms depend heavily on the presence of glutathione in the cells. Glutathione also functions to aid the removal of toxic heavy metals from cells. [52]

Our bodies must cope with free radicals as a part of living; however, when the body has to cope with excessive amounts of free radicals or radical oxygen species, the antioxidant enzyme systems and antioxidants can become depleted. In addition to ionizing radiation, chemicals including pesticides, insecticides, fungicides, and heavy metals such as mercury, cadmium and lead all cause excessive levels of cell-damaging free radicals.

For our antioxidant enzyme systems to work, our bodies must have adequate stores of specific minerals, amino acids —which are building blocks of protein— and various antioxidants such as vitamin C, alpha lipoic acid, CoQ10, etc. Just like you can't bake a cake if you run out of flour, eggs and baking powder, your body cannot combat free radicals if it doesn't have adequate nutrients to do the job of chemically modifying the molecules. When it comes to these antioxidants, variety is beneficial. See Table 5 for a wide variety of antioxidants.

Table 5. Various non-enzymatic antioxidants.

Alpha lipoic acid	Garlic (source of sulfur)
Bilberry	Ginkgo Biloba
Burdock	Grape seed
Vitamin A	Green tea
Vitamin C	Melatonin (take only at night time)
Vitamin E	Pycogenol (pine bark)
Coenzyme Q10	Selenium
Curcumin (Turmeric)	Silymarin (milk thistle)
Flavoniods	Omega-3 oils like fish oil

To quench the fire created by the reactive oxygen species produced by ionizing radiation, we need mineral dependent superoxide dismutase (SOD) enzymes that the body can only produce if the proper minerals, amino acids, and vitamins are available. There is copper/zinc SOD and

[52] Rosalie Bertell, International Journal of Health Services, "Depleted Uranium: All the Questions About DU and Gulf War Syndrome Are Not Yet Answered," 2006. p. 509 https://ntp.niehs.nih.gov/ntp/roc/nominations/2012/publiccomm/bertellattachmentohw.pdf

manganese SOD. Heavy metals in the body also deplete SOD and our detoxification systems. The main lesson is that without all of the necessary nutrients, our bodies cannot make the enzymes needed for neutralizing free radicals and reactive oxygen species. The result is more illness. I highly recommend reading “Fukushima Meltdown & Modern Radiation: Protecting Ourselves and Our Future Generations” by John W. Apsley, II. I learned from his book just how little I knew about radiation health effects and nutritional support.

Interestingly, the herbicide glyphosate in Roundup is a metal chelator that depletes manganese in plants and in our intestinal flora. Researchers have discovered that human consumption of food sprayed with glyphosate do not handle the mineral manganese correctly: too little goes where it is needed, while too much goes where it is not needed in the brain. [53]

For our bodies to detoxify heavy metals such as lead, mercury, cadmium, nickel, or uranium, our bodies must operate as chemical processing plants to rid our bodies of these toxins. To do this requires complex cellular processes and all the necessary raw materials such as sulfur, vitamins, minerals and amino acids. A shortage of even a single nutrient can stymie the detoxification process. And the stores of nutrients can get exhausted from the onslaught of multiple toxins.

For example, amino acid glutathione is a heavy metal detoxifier. But if sulfur, B vitamins to recycle cysteine from homocysteine, and antioxidants like vitamin C are not available, the body’s supply of glutathione runs short. But taking glutathione alone without taking the B vitamins to prevent homocysteine from building up misses the mark because elevated homocysteine is known to be damaging to cell membranes and increase the risk of cardiovascular disease. Vitamins B-6 and B-12 with folate work together to breakdown homocysteine.

The body can convert amino acid methionine into amino acid cysteine. But the mineral selenium is needed for methionine to be used in enzyme processes to neutralize the radical oxygen species (ROS) called the hydroxyl radical (OH-). Various nutrients are used up by the body’s trying to cope with ROS resulting from ionizing radiation.

Ionizing radiation causes the stripping off of electrons and this produces large amounts of radical oxygen species (ROS). The excessive amount of free radicals or ROS cause oxidative damage to cells. Metabolic enzymes such as superoxide dismutase (SOD) and catalase help break down ROS caused by ionizing radiation. But for SOD to function as an antioxidant, minerals zinc, copper and manganese are needed.

The amino acid taurine is needed to stabilize cellular membranes, particularly for the brain and heart. Taurine also requires cysteine and vitamin B-6. Taurine can be depleted by alcohol use and many metabolic disorders. A deficiency of taurine can harm the body’s ability to proper use

[53] Anthony Samsel and Stephanie Seneff, Surgical Neurology International, “Glyphosate, pathways to modern diseases III: Manganese, neurological diseases, and associated pathologies.” Received 2014, Accepted January 21, 2015., PMCID: PMC4392553.

sodium, potassium, calcium, and magnesium, all of which are necessary for normal heart rhythm. Seizures and poor brain function can be caused by taurine deficiency. Taurine and several other amino acids are also the building blocks for calming neurotransmitters, without which the person experiences anxiety and insomnia.

Lead or other heavy metals can interfere with the iron-binding proteins in the middle of a red blood cell. Various forms of anemia can result. Bone-seeking internal radionuclides include strontium-90, plutonium, and uranium. These radionuclides then irradiate stem cells in bone marrow, when our blood is made. Heavy metals or ionizing radiation can each adversely affect the health of blood cells.

Rosalie Bertell writes: "Heavy metal exposure (including uranium) can cause the loss of cellular immunity, autoimmune diseases, joint diseases such a rheumatoid arthritis, and diseases of the kidneys, circulatory system, and nervous system. Heavy metals supplant the normal calcium and other minerals in enzymes, and cause these molecules to lose their important functions in the body." [54]

While we normally ingest about 1.9 micrograms of natural uranium per day, 19 to 38 nanograms is absorbed through the intestines. However, when highly insoluble uranium forms are inhaled, only what can be dissolved by the body can be excreted. The rest is stored in the body. Highly insoluble particles may continue to circulate in blood and lymph fluid, irradiating these and surrounding tissues. [55]

It is my hope that by presenting this very brief, incomplete and simplified view of the cellular processes and the nutrients involved that the reader gain some concept of why every assault on the body's detoxification processes and supplies matters. This helps explain why anxiety, heart arrhythmias, and fatigue can be caused by heavy metal toxins, including uranium, in the body. It highlights the importance of correcting any and all nutritional deficiencies— deficiencies that can result from coping with the onslaught of radionuclides and chemical toxins in our bodies.

You know you are supposed to eat protein. But the body needs adequate vitamin C, adequate sulfur from onions and garlic, cabbage, adequate B vitamins in an absorbable form, as well as adequate specific amino acids from protein. Missing an ingredient can mean the body can't replenish its depleted stores of glutathione and must shuttle the toxins into body storage until such time that it can cope with detoxifying the contaminant and excreting it.

Throwing antioxidants at the body such as vitamin C, pine tree bark, and phytochemicals known as oligomeric proanthocyanidins will help. But without the proper B vitamins or amino acids, you still can't make glutathione. And you won't be avoiding the buildup of homocysteine.

[54] Rosalie Bertell, International Journal of Health Services, "Depleted Uranium: All the Questions About DU and Gulf War Syndrome Are Not Yet Answered," 2006. p. 510. https://ntp.niehs.nih.gov/ntp/roc/nominations/2012/publiccomm/bertellattachmentohw.pdf

[55] Rosalie Bertell, International Journal of Health Services, "Depleted Uranium: All the Questions about DU and Gulf War Syndrome Are Not Yet Answered," 2006. p. 513, 515. https://ntp.niehs.nih.gov/ntp/roc/nominations/2012/publiccomm/bertellattachmentohw.pdf

I found supplementation of glutathione helpful, despite literature that said direct glutathione supplementation probably wasn't effective. But with that said, there is no getting around the need to try to eat properly even if supplementation of nutrients is also supplied.

Finding out what heavy metals you have been exposed may be helpful but difficult. But it is as important or perhaps more so to identify and fix nutritional deficiencies so that your body can remove these toxins.

Proper nutrition is not going to correct improperly repaired broken DNA strands from alpha radiation. The incorrectly repaired double-ended DNA breaks replicate. The birth defects risk is not likely to be avoided either. What it may do, however, is help to restore energy, reduce inflammation, and keep you healthy and alive longer after relatively low radiation and/or chemical exposure.

Cancer and leukemia are not the only adverse health impacts of radiation. By understanding the role of heavy metals in inflammation, adrenal stress, and elevated heart beat, you can now began to understand why some studies of radiation exposure following the 1986 Chernobyl accident have found elevated circulatory and heart disease problems.

Carbon tetrachloride, CCL4, is a toxin shown to act by a free radical mechanism by stimulating lipid peroxidation that damages cells. Carbon tetrachloride poisoning may damage both the liver and kidneys. Tetrachloroethane (TCE) is a solvent and can cause liver damage. Reductive dehalogenation of TCE through natural or induced mechanisms may result in production of vinyl chloride which, in contrast to TCE, is a known carcinogen. [56] TCE is known to be heavier than water, therefore once it is in the Snake River Plain aquifer, it will be found deeper in the aquifer as it flows downgradient.

Supporting Your Antioxidant Systems

Damage done by ionizing radiation and chemical toxins will not necessarily be alleviated by supporting the body nutritionally. Nor will handfuls of supplements replace the need for eating a healthful diet of vegetables, fruits, proteins and healthy fats. But isn't rather foolish to expect the body to cope with high levels of oxidative stress without supplying the necessary nutrients it needs?

When you understand more about the role of various nutrients, you may be more likely to endeavor to include them in your diet, and perhaps supplement certain nutrients. Nutritional needs go far beyond counting calories, and an understanding of carbohydrates, fats and proteins.

Let me just say this: when it comes to nutritional supplementation, many people don't know what they are doing. The healthier you are, the more you may stumble along without much

[56] Hugh H. Russell et al., EPA Ground Water Issue, "TCE Removal from Contaminated Soil and Ground Water," EPA/540/S-92/002, January 1992.

problem. But once your health is struggling, the challenge of determining which supplements may be beneficial is not a trivial one. And you can upset the balance of various nutrients by taking some supplements.

The vitamin supplement that works beautifully for one person may be detrimental for another person. People have different genetic backgrounds, allergy and autoimmune tendencies, digestive traits, and varying amounts of money to spend on supplements which generally are not covered by medical insurance.

Here are some general points to keep in mind about choosing supplements:

1. **Steer toward well-established supplement companies** — they have established a track record for good quality products at competitive prices. I avoid the unfamiliar brands of drug store supplements that tend to be laden with artificial dyes, other unnecessary ingredients, and often the least effective ingredients.
2. **Always read the label of ingredients in a supplement.** You may need to avoid any potential allergy-causing ingredients. Try to get gel capsules rather than compressed tablets or caplets which can be harder to dissolve and digest. Note the pill size because larger sized compressed caplets can be difficult to swallow. Take note of how many pills it takes to get the serving size, typically in milligrams of active ingredient. I have mail ordered supplements from these low cost suppliers for years: vitacost.com and swansonvitamins.com. Both are reliable companies with their own brand as well as many other well-known brands. On-line supplement shopping gives you time to examine the label for the amount of active ingredients as well as price compare and I tend to learn a few things to watch out for from reading the product reviews.
3. **Understand that you are unique.** Your blood type, [57] your genetics, and your present state of health will all affect whether a particular supplement is right for you.
4. **Always talk to your doctor or pharmacist before taking new supplements or herbs** especially if you are taking prescription medications.
5. **Learn from the doctors who write books and who have had success treating patients with chronic illness: a successful supplement protocol usually includes more than one nutritional ingredient.** Their protocols include a group of nutrient players to support a particular issue, whether it is digestion, detoxification, or a sleep issue. In other words, don't take a single nutrient, fail to get improvement and then give up. Also, multiple protocols may be taken at once.
6. **Some supplements taken alone may unbalance other nutrients in the body.** While B-12, vitamin D, and fish oil can be taken alone, other minerals and vitamins taken alone may deplete others. Zinc and copper balance can be disrupted by taking zinc. Calcium needs to be balanced with magnesium, for example, and good bone formulas include many supportive nutrients in addition to calcium.
7. **Don't be like a fireman throwing a teacup of water on a raging fire who then concludes that water does not put out fires.** The right nutrient combination, in the right

[57] Peter J. D'Adamo, "Eat Right For Your Type – Complete Blood Type Encyclopedia," Riverhead Books, 2002. While not widely accepted, I have found that blood type does provide a good general place to begin to understand whether a food or supplement will be compatible with a person.

dose, taken at the right time can be extremely beneficial to support healing. And just like with many prescription drugs, it can take some experimenting to get it right for you.

8. **Some supplements are needed routinely and others are used only for a few weeks.** Use routinely: vitamin D, fish oil, a multivitamin, and antioxidant support. Other supplements such as specific amino acids may be used only as needed or only for a few weeks or perhaps longer to see if it gets you back on track.
9. **Some supplements must be restricted in dosage to an amount close to the typical US recommended daily allowance or you risk taking an unhealthy amount.** Other supplements, like B-12, can be taken in very high amounts, exceeding the typical RDA. Sticking close to the RDA is generally safe, but for some supplements you can safety exceed the RDA. For minerals and iodine, you typically would not want to exceed the RDA at all or by more than a factor of two but only for a limited time.
10. **For people with autoimmune issues, you already know you must be especially careful.** I know people with juvenile onset diabetes and some of these folks can't experiment with salad dressings. These folks have to be incredibly careful. They may need to add one supplement at a time at minimal dose to see their reaction to it, and they must avoid immune system strengthening or agitating supplements. These are folks that really need to tune in and follow their intuition about whether a supplement "feels" right for them. These are also the folks that must be especially careful about chelation, herbs or supplements that draw heavy metals or other toxins from the tissue more rapidly than their body can cope with detoxifying it and expelling it.
11. **If you have cancer or other active disease, there may be some resources (I mention a few books in this report) to help you understand how to support yourself nutritionally during or after treatment.** When you are being treating for cancer, you must be particularly careful not to interfere with any prescribed medical treatments or procedures.
12. **Listen to your body.** Learning to listen to your body can be extremely useful. Your logical mind might be saying you need to take a large amount of vitamin C. But your body may be saying to you, no, not today. Vitamin C supplements can make the body more acidic. Sometimes a lower amount of a more natural form of vitamin C is healthier than a larger, and perhaps less expensive corn-based vitamin C. Learn to listen to your body and your intuition.

Understanding Your Body's Detoxification Systems

Understanding your body's detoxification systems is extremely important particularly if you've experienced high oxidative stress, environmental toxins or high levels of medical drugs. Most people do not know about their liver's Phase I and Phase II detoxification systems. If your brain is clear, you feel calm, your sleep is restful, and your energy is abundant, you may not need to read this. If not, probably you do.

There are many ways that your body detoxifies various substances. Each toxin requires a particular recipe to detoxify the substance and the recipe requires various minerals, vitamins, amino acids, and antioxidants. If your body is good at performing Phase I, but runs out of nutrients to perform Phase II, you get exposed to toxins remaining from Phase I. It is very important to get Phase II operating well before you take nutrients that stimulate Phase I. Likewise, it is very important to get both Phase I and II operating well before you introduce substances that may pull toxins out of the tissues. Cilantro, for example, pulls mercury out of storage in the body.

First, it is important to understand just how important your detoxification processes are. With that knowledge, then you begin to understand why it is crucial to maintain adequate supplies of the many nutrients your body needs for detoxifying. Table 6 highlights some of the important detoxification Phase I and II systems, the toxins detoxified, and the nutrients needed.

A sign that your Phase I detoxification system doesn't have an ample supply of the nutrients it needs is that perfumes or gasoline fumes bother you — when they didn't bother you before. A sign that your glycination system doesn't have an ample supply of the nutrients it needs is that the commonly used preservative using benzoates trigger your bladder whether in a sinus spray or in food.

Your necessary detoxification system supplies could be minerals such as magnesium, which gets used up by high sugar intact, high levels of inflammation, or high toxin load. Other minerals such as manganese could be more of a problem: the common herbicide Roundup not only reduces manganese levels in food, it alters the proper usage of the mineral in the body. This means that simply adding more manganese to the diet may not solve the problem.

Various vegetables and fruits begin to take on a new importance as you understand the need for sulfur from onions, garlic and cabbage — and the limonene component of citrus fruits.

Finally, you will want to get acquitted with amino acids. Table 7 provides some key information for some of the amino acids. These building blocks of protein each have a different role to play in health. As with all nutrients, getting the nutrient from food is ideal. But the therapeutic value of specific amino acids needs to be understood, both to modify ones diet and sometimes to consider supplementation.

Table 6. Highlights of Phase I and Phase II detoxification.

Phase and Process	**Toxins Neutralized**	**Food or Supplement Support**
Phase I	Alcohol, drugs, exhaust fumes, pesticides, perfumes. (Slow caffeine clearance indicates slow Phase I.)	Magnesium, vitamin C, copper, zinc, B-complex vitamins. Cabbage family. Limonene. Glutathione.
Phase II		
Glutathione conjugation	Fat-soluble toxins including heavy metals (lead, mercury, cadmium), solvents, pesticides	Glutathione to make toxins water soluble. C, B-2, B-6 selenium, zinc, N-acetyl-cysteine, milk thistle.
Glycination (amino acid conjugation)	Benzoate clearance, aspirin	Glycine, taurine, glutamine, arginine, ornithine

Methylation	Estrogens. Preventing stagnation of bile flow.	S-adenosl-L-methionine (SAMe) which the body makes from choline, B-12, folate, B-6 and methionine.
Sulfation	Drugs, food additives, environmental toxins, acetaminophen, intestinal bacteria, neurotransmitters	Sulfate, taurine, glutathione, methionine, cysteine, adequate molybdenum. Sulfur rich foods include onions, garlic, broccoli, Brussels sprouts. Soaking in Epsom salts is beneficial because it is magnesium sulfate.
Sulfoxidation	Sulfite sensitivity, asthmatics, strong urine odor if asparagus is eaten.	Molybdenum
Acetylation	Sensitivity to sulfa drugs, antibiotics	B-1, B-2, B-5, C
Glucuranidation	Sedatives, aspirin, menthol, vanillin, benzoates, fungal toxins, some hormones. Poor if you have Gilbert's syndrome.	Limonene. Green tea.

Source: Information about the body's Phase I and II detoxification systems can be found in many books. A readable source is: Michael Murray, ND and Joseph Pizzorno, ND, "Encyclopedia of Natural Medicine," 2nd Ed., Prima Health, 1998.

Table 7. Highlighting the role that amino acids play in various conditions.

Symptom or Process	Amino Acids	Comments
Anemia	Histidine or Carnosine Citrulline Isoleucine Lysine	Two main types of anemia are iron deficiency anemia, B-12/folate deficiency. But heavy metal toxins (lead, cadmium, etc.) can also be a factor as well as other diseases. Oxalates inhibit iron absorption.
Metal chelating	Histidine Glutathione Cysteine (N-acetyl-cysteine) Methionine	Glutathione helps escort heavy metals out of the body. Don’t be deficient in glutathione when nutrients such as cilantro are taken that pull heavy metals out of the tissue and into the blood stream.
Heart Arrhythmia	Carnitine Histidine Taurine Avoid buildup of homocysteine (see brain)	Taurine helps stabilize cellular membranes. Note that the mineral magnesium is the muscle relaxation mineral and magnesium deficiency can cause muscle cramps. CoQ10 is supportive.
Brain	Avoiding buildup of homocysteine Acetyl-L-carnitine	The body needs to recycle homocysteine into cysteine. To avoid unhealthy buildup of homocysteine, the body requires B-12, B-6, folate.
Detoxification	Citrulline Cysteine Glutathione Glycine Methionine Taurine	Glutathione is very important to Phase I and Phase II detoxification systems. Glutathione is made up of cysteine, glycine and glutamic acid. Supporting detoxification processes is essential following radiation, chemical, and heavy metal exposures.
Liptropic (avoid gallbladder sludge so that bile is moving out of the liver for	Cysteine Methionine Taurine	Supportive nutrients are choline from lecithin and inositol.

detoxification)		
Fatigue	Carnitine Tyrosine	The get-up-and-go hormone adrenaline is made of tyrosine, B-6 and vitamin C. You cannot fix adrenal fatigue without the basic building blocks of adrenaline.
Tissue repair	Arginine Ornithine Glutamine	The building blocks of growth hormone need to be available so that tissues can be repaired during deep sleep. Glutamine helps repair gut tissue. A healthy gut is essential for nutritionally supporting the brain and body.
Insomnia/Anxiety	GABA (gamma-aminobutyric acid) Glycine Tryptophan Taurine SAMe helps lower homocysteine and also may support glutathione levels and brain neurotransmitters such as serotonin and also melatonin which support sleep.	GABA is calming for most people but suggests leaky blood-brain barrier. If GABA increases anxiety, your brain may be using it for fuel. The body can make more tryptophan if it has ample B-3 (niacin). SAMe is also supportive of tryptophan production. Epilepsy is associated with deficiency of glycine and taurine, as well as manganese.
Sugar cravings	Glutamine	Glutamine also helps heal the intestinal lining.

Note: IMPORTANT: Understanding some of the beneficial actions of some amino acids should encourage you to eat a healthy diet. If you choose to supplement any amino acid, you need to further research the precautions and talk to your doctor.

Inadequate amino acids such as taurine, for example, also adversely affect heart health. Heavy metal toxins can deplete taurine and glutathione.

When it comes to brain and heart health, most people would not think of B vitamins or amino acids. However, elevated levels of homocysteine contribute to brain and circulatory issues. To prevent buildup of homocysteine, the body requires vitamin B-12, B-6 and folate (or folic acid). I find very few people who understand this although it has been frequently written about. Taking stomach acid inhibitors is very popular: but it can reduce B-12 absorption as well the absorption of other minerals and nutrients. If supplementing vitamin B-12, the methyl form of B-12 and folate is recommended for better absorption. If a B-12 injection, that typically requiring a prescription, helps you feel better, then you know you’ve been needing more B-12. But you need to consider your folate and B-6 levels as well as other nutrients you may be deficient in.

For the heart muscle, calcium and magnesium need to be in balance. The medical industry has decided to lower calcium by calcium channel blockers. Doesn’t raising magnesium levels instead make more sense? Perhaps because they find adequate magnesium levels in blood serum, without testing inside the cells, hides the magnesium shortage. Signs of magnesium deficiency include anxiety and muscle cramps. If soaking in Epsom salts, made of magnesium-sulfate, really relaxes you, then you are probably needing more magnesium. Soaking in Epsom salts aids detoxification, muscle relaxation, and really is soaked in through the skin.

Time for a Neurotransmitter Check?

Understanding the brain’s neurotransmitters seems to become more important as we age. Understanding the four main neurotransmitters of dopamine, acetylcholine, serotonin, and GABA and recognizing the signs of deficiency can be helpful. Included in Table 8 are possible nutrients and exercises to boost each neurotransmitter can be very helpful with small imbalances.

Digestive problems can lead to nutrient deficiencies that can lead to neurotransmitter problems. In any case, neurotransmitter problems will arise if the nutrients needed to for the body to make the neurotransmitter are not in ample supply. The important role of amino acids, B vitamins, choline and essential fatty acids, and minerals in making neurotransmitters can be seen in Table 8.

Table 8. Neurotransmitters: deficiency symptoms and support.

Signs of Neurotransmitter Deficiency	
Dopamine - Get up and go deficiency Crave caffeine and stimulants which eventually deplete dopamine. Depression, desire to isolate Inability to finish tasks Difficulty making decisions Easily distracted Parkinson's is extreme low dopamine Low thyroid decreases dopamine Support dopamine with Tyrosine, B-12 plus folate, phenylalanine, B-6, iron, copper, C, SAMe, NADH, theanine. Weight lifting, anaerobic exercise. Brain: Frontal lobes, Beta waves	**Serotonin – Joy Deficiency** Crave sweets and carbs Depression and overwhelm Lack of enthusiasm, joy Sleep is not deep or restful Insomnia, pain, allergies Obsessive-compulsive disorder Multiple sclerosis Support serotonin with Tryptophan, calcium, magnesium, essential fatty acids, zinc, B-3, B-6, B-12 plus folate, SAMe, cherries, pumpkin seeds, Aerobic exercise, prayer, meditation, yoga Brain: Occipital lobes – delta waves
Acetylcholine – Nerve health Anxiety Dry mouth Inflammatory disorders Attention problems Dehydration MS, myelin sheath issues Support acetylcholine with Choline, eggs, phosphatidyl choline, and phosphatidyl serine, omega-3 essential fatty acids (EFAs), alpha lipoic acid, taurine, carnitine, ginseng. Aerobic exercise Brain: Parietal lobes – alpha waves	**GABA – Need a chill pill?** Anxiety Insomnia Overwhelmed Allergies Difficulty concentrating Support GABA with GABA, glutamine, inositol, B-3, B-6, phospatidyl serine, holy basil, aerobic exercise. Brain: Temporal lobes, Theta

The Journey from Chronic Illness to Health

I recognize that nutritional supplements may not provide a cure for everyone. Successful dietary and supplementation approaches are not simple. But I hope that I have introduced the reader to the concept that without proper nutritional support, it is difficult or impossible to get well.

Commonly prescribed medications such as stomach acid inhibitors, pain relievers, sedatives, and antidepressants have a role. But these common medications also deplete our body's detoxification nutrients. A common scenario is that an overworked person doesn't have time to eat properly. They are not able to get enough sleep for various reasons. They may have thyroid issues that in the past were not diagnosed as readily as today. They begin to have joint pain and digestive problems. They begin taking more medications. Their health problems seem to worsen and they are told it is simply due to aging. Going to the doctor with multiple symptoms leads to a prescription of an antidepressant.

Add to this ionizing radiation, ingestion of hexavalent chromium, carbon tetrachloride, or other toxic chemical in drinking water in the work place, or other chemical exposures at home, in our pesticide laden food, and cell disrupting levels of electromagnetic radiation from cell phones and other wireless devices, and the downward spiral proceeds faster.

The anxiety they feel increases and they are not told of the physical reasons for increasing anxiety could be due to their over-taxed detoxification system. More medications are prescribed, and rarely does the medical practitioner consider the potential chronic exposures to radiation or chemicals that the patient may have had.

Some doctors who are champions of treating chronic illnesses have written books. One of these champions is Richard Horowitz, MD, "How Can I Get Better?" (See full references in the Recommended Reading section at the end). Some of his patients have seen dozens of doctors before finding Horowitz and getting on the path to being well. Horowitz uses extensive testing including testing for heavy metals. He uses several nutritional protocols because he understands that for the body to heal, you must address digestive health, provide deep restorative sleep, address heavy metal and other toxins, strengthen the body's detoxification systems and so forth — in addition to treating a disease such as Lyme.

Another champion doctor in my opinion is Dati Kharrazian, DHSc, DC, MS, author of "Why Isn't My Brain Working" and "Why Do I Still Have Thyroid Symptoms When My Lab Tests Are Normal?" This is another doctor who knows the importance of solving any heavy metal toxin issues and the importance of restoring nutritional support for the brain. He doesn't shy away from the complexity and variation of issues that each person may have that need to be addressed in order to promote health.

Finally, if you are already coping with a disease like cancer, the number of books and information — and the amount of conflicting information — is mind boggling. My hope is that more health practitioners will learn about ways to help patients recover from their cancer treatments to more quickly and fully restore health. And so I end with the recommended reading list that follows.

Recommended Reading

Lise N. Alschuler et al., "The Definitive Guide to Cancer – An Integrative Approach to Prevention, Treatment, and Healing," 3rd Ed., Celestial Arts Berkeley, 2010.

Edouard I. Azzam et al., *Cancer Letter*, "Ionizing radiation-induced metabolic oxidative stress and prolonged cell injury" 2012 December.
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3980444/

John W. Apsley, II, MD(E), ND, DC, "Fukushima Meltdown & Modern Radiation: Protecting Ourselves and Our Future Generations," Temet Nosce Publications, 2011. ISBN 978-0-945704-97-2

Phyllis A. Balch, CNC, "Prescription for Nutritional Healing," 4th ed., Penguin Group, 2006.

Peter J. D'Adamo, "Eat Right For Your Type – Complete Blood Type Encyclopedia," Riverhead Books, 2002.

Robert O. Becker, MD, and Gary Selden, "The Body Electric – Electromagnetism and the Foundation of Life," 1985.

Steven M. Cruker, "Altered Genes, Twisted Truth – How the Venture to Genetically Engineer our Food Has Subverted Science, Corrupted Government, and Systematically Deceived the Public," Clear River Press, 2015.

Richard I. Horowitz, MD, "How Can I Get Better? – An Action Plan for Treating Resistant Lyme & Chronic Disease," St. Martin's Press, February 2017.

Datis Kharrazian, DHSc, DC, MS, "Why Isn't My Brain Working" A revolutionary understanding of brain decline and effective strategies to recover your brain's health." Elephant Press, 2013.

Donald Lepore, ND, "The Ultimate Healing System – The Illustrated Guide to Muscle Testing and Nutrition," 1985.

Michael Murray, ND and Joseph Pizzorno, ND, "Encyclopedia of Natural Medicine," 2nd Ed., Prima Health, 1998.

Michael Murray, ND et al., "How to Prevent and Treat Cancer with Natural Medicine," Riverhead Books, 2002.

Sherry A. Rogers, MD, "No More Heartburn – Stop the Pain in 30 Days – Naturally! – The Safe, Effective Way to Prevent and Heal Chronic Gastrointestinal Disorders," Kensington Books, 2000. [Many of Sherry Rogers' books can be found at Needs.com and all are highly recommended for the person seeking to regain health.]

Thomas J. Slaga, PhD, "The Detox Revolution, ISBN 0-8092-9976-3, 2003.

Jerry Tennant, MD MD(H) PScD, "Healing is Voltage – The Handbook," 3rd. ed., 2013.

Jerry Tennant, MD MD(H) PScD, "Healing is Voltage – Cancer's On/Off Switches," 2015.

Current Maximum Contaminant Levels for Drinking Water

A table of federal drinking water maximum contamination levels (MCLs) is given in Table 9, with emphasis more on long-lived radionuclides. It is important to recognize that staying just below the MCLs will probably not protect human health. Public health goals are typically 0 for radionuclides. For a listing of beta emitter limits in pCi/L to equal 4 mrem/yr for an individual radionuclide, see this table: http://www.iem-inc.com/information/tools/maximum-contaminant-levels-for-water . Tritium, although a beta emitter, is considered separately with MCL 20,000 pCi/L. Gross alpha is limited to 15 pCi/L, excluding uranium, Uranium is limited to 30 micrograms/L, and combined Radium-226/-228 is limited to 5 pCi/L. Non-radiological contaminants are also included in the table.

Table 9. Typical aquifer contaminants of concern at the Idaho National Laboratory.

Constituent	Regulatory maximum contaminant level[1]	Natural background level	Location of Primary Interest[2]
Radionuclide (half-life, main decay mode)			
Tritium (12.3 year, beta)	20,000 pCi/L	0 to 150 pCi/L	INTEC, ATRC, RWMC, TAN, NRF, other areas
Carbon-14 (5730 year, beta)	2,000 pCi/L	0	RWMC
Chlorine-36 (301,000 year, beta)	700 pCi/L	0	RWMC, INTEC
Iodine-129 [3] (17,000,000 year, beta and gamma)	1 pCi/L	0 to 0.0000054 pCi/L (DOE/ID-22225, 2013)	RWMC, INTEC
Technetium-99 (213,000 year, beta)	900 pCi/L	0	RWMC, INTEC 2,200 pCi/L and increasing trend.
Neptunium-237 (2,144,000 year, alpha)	15 pCi/L	0	RWMC
Cesium-137 (30.2 year, beta)	200 pCi/L (previously 160 pCi/L)	0	RWMC, INTEC, ATRC, TAN, MFC
Strontium-90 (29.1 year, beta)	8 pCi/L	0	RWMC, INTEC, ATRC, TAN
Uranium-238 (4,470,000,000 year, mixed, alpha)	10 pCi/L	0	RWMC, TAN, INTEC
Total uranium	(30 ug/L)	<3 pCi/L or < 2 ug/L [7]	RWMC, TAN, INTEC, TRA, NRF
Uranium-234, pCi/L	(Note: 8)	1.36 pCi/L [7]	see total uranium
Uranium-235, pCi/L	(Note: 8)	0.025 pCi/L [7]	see total uranium
Uranium-238, pCi/L	(Note: 8)	0.541 pCi/L [7]	see total uranium
Uranium-233, pCi/L	(Note: 8) from thorium cycle	0	see total uranium
Uranium-236, pCi/L	(Note: 8) from neutron capture in a nuclear	0	see total uranium

	reactor		
Gross alpha [4]	15 pCi/L		
Gross beta/gamma [5]	4 mrem/yr (8 pCi/L derived from 4 mrem/yr based on Sr-90)	7 pCi/L (DOE/ID-11492, 2013)	
Organic Compounds			
Carbon tetrachloride (CCl_4)	5 u/L	0	RWMC, INTEC
Methylene chloride	5 u/L	0	RWMC
Tetrachloroethylene (PCE)	5 u/L	0	RWMC, TAN
Trichloroethylene (TCE)	5 u/L	0	RWMC, TAN 1350 ug/L
Inorganic Analytes			
Nitrate	10 mg/L	0.655 mg/L from USGS 2016 [9]	INTEC, RWMC, MFC
Chromium	100 ug/L	<1.9 ug/L [10] Hexavalent chromium should be 0	Primarily TRA now ATRC. Also RWMC, TAN, INTEC, PBF, NRF
Sodium	(an indicator of nuclear process waste)	8.3 ug/L from USGS 2016 [9]	1.5 million lb/yr discharged by INL during 1989-1991 at INTEC, ATRC, NRF, CFA, MFC

Units: pCi/L = picocurie/liter; mg/L = milligram/liter; ug/L = microgram/liter; mrem/yr = millirem/yr; lb= pound.

Table Source: Department of Energy, *Operable Unit 7-13/14 Five-Year Monitoring Report for Fiscal Years 2010-2014*, DOE/ID-11507, August 2014, and Idaho Cleanup Project, *Five-Year Review of CERCLA Response Actions at the Idaho National Laboratory*, DOE/NE-ID-11201, Revision 3, February 2007.

Table Notes:

1. Maximum contaminant level from US Environmental Protection Agency for drinking water, 10 CRF 141.
2. Some monitored locations indicated here may apply to perched water rather than the aquifer. RWMC soil sampling is also included.
3. "I-129 is monitored for indirectly by analyzing for Tc-99" at the RWMC superfund site; USGS tends to report I-129 but not Tc-99. USGS monitoring of Tc-99 reported in journal articles rather than accessible USGS reports.
4. Gross alpha includes radium-226 but excludes radon and uranium. The activity of uranium having a natural composition can be estimated from mass in microgram/Liter by multiplying by 0.67 pCi/microgram.
5. Gross beta excludes naturally occurring potassium-40.Gross beta given here is based on strontium-90.
6. Facilities are Advanced Test Reactor Complex (ATRC) formerly the Test Reactor Area and Reactor Technology Complex; Central Facilities Area (CFA); Idaho Nuclear Technology and Engineering Center (INTEC), formerly the Idaho Chemical Processing Plant; Materials and Fuels Complex (MFC) formerly Argonne National Laboratory – West; Naval Reactors Facility (NRF); Power Burst Facility (PBF);Radioactive Waste Management Complex (RWMC); Test Area North (TAN).
7. Uranium background level estimated from USGS report 2016-5056 (DOE/ID-22237) Table 1 values for western tributary, median values for U-234, U-235, and U-238 in picocuries/liter, converted to micrograms/liter by dividing by 0.67 pCi/ug.
8. The uranium limit is for total uranium, the sum of each uranium isotope after converting reported activity (pCi/L) to mass uits (ug/L).
9. Chromium was sampled in the Birch creek area in USGS 2003-4272, off INL site levels below 1.9 ug/L.
10. Nitrate and sodium background level from USGS report 2016-5056 (DOE/ID-22237) Table 1 values for western tributary, median values for U-234, U-235, and U-238 in picocuries/liter, converted to micrograms/liter by dividing by 0.67 pCi/ug.

The federal limit for tritium in drinking water is 20,000 pCi/L (picoCurie/liter). But is it safe to drink even 100 pCi/L? The answer to this question is no it is not safe and don't believe the NRC, the DOE or the Health Physics Society. The reason is that the total energy imparted by tritium is not as important at the fact that the hydrogen in tritium is incorporated into the body's DNA. The damage caused by the radioactive decay is not randomly dispersed as is cosmic radiation to the body during an airplane ride. While powerful industry interests lobby to keep federal limits for tritium high, **the State of California declared a drinking water goal for tritium of less than 100 pCi/L.**

A 1990 USGS report states that an increased allowable maximum contaminant level for tritium was coming and that implied that no one should be concerned about exceeding the current MCL. [58] MCLs change and so the USGS should not be focused on telling people not to worry because the monitoring did not consistently exceed the current MCL. The USGS has curiously avoided, for many decades of INL monitoring, what normal background levels should be, because that would have put on display the elevated levels. Rather than commenting on potential future changes to MCLs, the USGS should have been more carefully selecting adequate detection levels for tritium and hexavalent chromium because the better capability was often available then they used.

After seeing the adverse health effects of hexavalent chromium, also called chromium-6, the state of California has not only reduced the regulatory limit for hexavalent chromium from the EPA's 100 micrograms/liter to 10 micrograms/liter, **California also created a public health goal to limit hexavalent chromium to 0.02 micrograms/liter.** [59]

California regulators say that 0.02 ug/L yields a 1 in a million risk of cancer. So drinking water with hexavalent chromium at 100 ug/l is a cancer risk of 1 in 200, for a person drinking it for 70 years. It should be noted for perspective that 31,130 lb of hexavalent chromium admittedly dumped into the aquifer would require almost the entire aquifer to dilute to the public health goal of 0.02 ug/L. Of course, the plumes of hexavalent chromium are not diluted over the entire aquifer as they flow downgradient to the Magic Valley.[60] The EPA continues to investigate chromium but has not changed the federal MCL. [61]

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[58] USGS Report 90-4090, L.J. Mann and L.D. Cecil, "Tritium in Ground Water at the Idaho National Engineering Laboratory, Idaho," June 1990. p. 32 and 34. http://pubs.usgs.gov/wri/1990/4090/report.pdf

[59] California state resources board for chromium-6 (hexavalent chromium) at http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/Chromium6.shtml

[60] The Snake River aquifer is roughly 2.44E+15 liters. Contamination is not diluted by the entire aquifer but spreads in unevenly diluted amounts of contamination as the contaminated waste water in the aquifer flows in fast paths and in slow paths downgradient, fanning out and spreading south, southeast and southwest from the source of contamination. For perspective only, to dilute 31,130 lb of hexavalent chromium to 0.02 micrograms/Liter would take 7E+14 Liters.

[61] American Water Worker Association, Chromium in Drinking Water: A Technical Information Primer at http://www.awwa.org/Portals/0/files/legreg/documents/UpdatedChromiumInDrinkingWaterSummaryFinal.pdf