

Public and Worker Health Impacts from the Fukushima Nuclear Plant Accident

Thomas McKone, PhD & James Seward, MD, MPP



JAPAN EARTHQUAKE & TSUNAMI RELIEF ORGANIZATIONS

- Doctors Without Borders/Médecins Sans Frontières: Doctorswithoutborders.org
- The Red Cross: Redcross.org
- International Medical Corps: Internationalmedicalcorps.org
- The Japan Earthquake and Tsunami Relief Fund: GlobalGiving.org
- Japan Society of Northern California: Japan Earthquake and Tsunami Relief Fund give2asia.org/japansociety
- Operation USA: OpUSA.org
- UNICEF: www.unicefusa.org
- Salvation Army: SalvationArmyUSA.org
- The International Fund for Animal Welfare: www.IFAW.org

Western Occupational and Environmental Medical Association
CME Webinar - April 6, 2011

Public and Worker Health Impacts from the Fukushima Nuclear Plant Accident

Speakers:

Thomas E. McKone, PhD, University of California, Berkeley
Lawrence Berkeley National Laboratory

AND

James P. Seward, MD, MPP, Medical Director
Lawrence Livermore National Lab

**PLEASE STAND BY
WEBINAR WILL BEGIN AT 12:00pm (PDT)**

For Audio:
Call: 866-740-1260
Access Code: 7644915#

Faculty Disclosure:
Thomas E. McKone, PhD and James P. Seward, MD, MPP have no conflicts of interest to disclose.

Western Occupational and Environmental
Medical Association (WOEMA)

Public and Worker Health Impacts from the Fukushima Nuclear Plant Accident

An Environmental Health Perspective

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Lawrence Berkeley
National Laboratory



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Overview

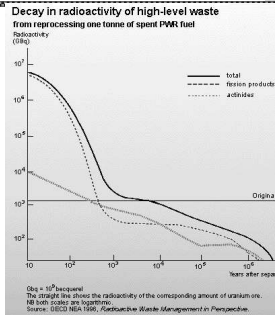
- Nuclear Power Plants and Nuclear Safety
- What Went Wrong at Fukushima
- Radiation hazards and radiation protection
- Types, origins, and potential health effects of the radioactivity released in a reactor accident



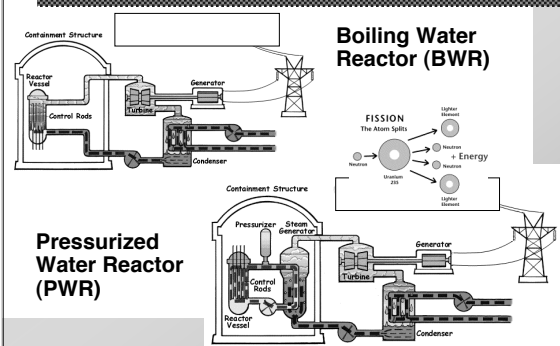
Nuclear Power Plants & Nuclear Safety

- Reactor Design
 - Boiling water reactor (BWR)
 - Pressurized water reactor (PWR)
- Containment
- Defense in depth
- Decay heat

Heat produced by the decay of radioactive fission products after a nuclear reactor has been shut down—a major safety concern



Reactor Design (BWR vs PWR)

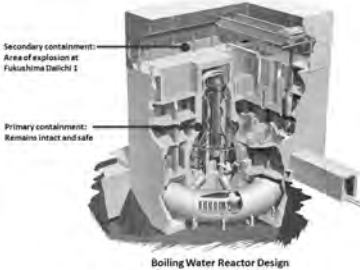


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The Fukushima BWR Design

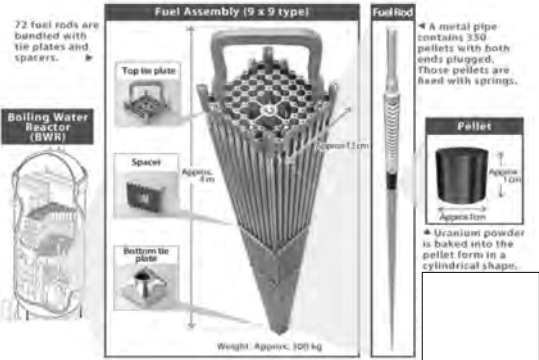
- Mark 1 containment
- Relatively small containment volume
- Suppression pool to cool and contain core emissions



Boiling Water Reactor Design

BWR Fuel Assemblies (548)

72 fuel rods are bundled with tie plates and spacers.



Boiling Water Reactor (BWR)

Fuel Assembly (9 x 9 type)

Top tie plate

Spacer

Approx. 8 m

Bottom tie plate

Weight: Approx. 300 kg

Fuel Rod

Pellet

Approx. 1 cm

Approximate

A metal pipe contains 350 pellets with both ends plugged. These pellets are held with springs.

Uranium powder is baked into the pellet form in a cylindrical shape.

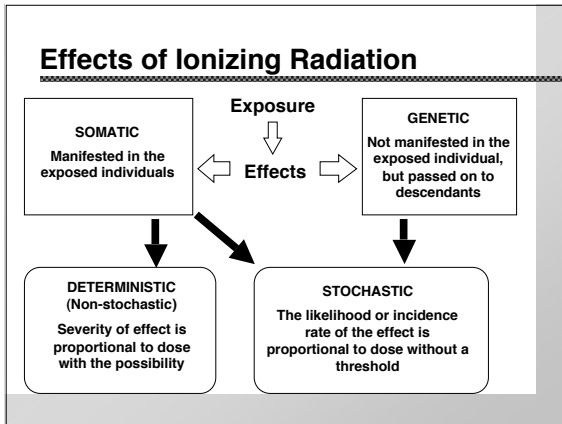
Radiation Hazards and Radiation Protection

- Effects of ionizing radiation
- Energy, power and radiation
- Measures of radiation
- Ionizing and non-ionizing radiation
- Biological damage from radiation
- Background radiation
- ICRP* standards

*The International Commission on Radiological Protection

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Energy, Power, and Radiation

- Radiation is the transfer of energy through space
- Energy is the ability to do work (or damage) and is measured in joules, $1 \text{ J} = 1 \text{ newton-m}$
- Power is the rate at which energy is delivered and is measured in watts, $1 \text{ W} = 1 \text{ J/s}$
- A radioactive substance emits radiation and has radioactivity measured in disintegrations/s (becquerels, or Bq)

Ionizing and Nonionizing Radiation

- Ionizing radiation includes both particles and electromagnetic radiation
- Ionizing radiation has sufficient energy to break chemical bonds in molecules and cause formation of ion pairs
- Nonionizing electromagnetic radiation does not have sufficient energy to break chemical bonds

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Tissue Dose as the Basis Effects

□ Absorbed tissue dose is proportional to energy deposition in the tissue, measured in joule per kg

□ The unit of absorbed dose is the gray (Gy)

$$1 \text{ J/kg (tissue)} = 1 \text{ Gy} = 100 \text{ rad}$$

□ The absorbed dose alone is insufficient to predict the probability of harm

Dose Equivalent

□ Thus, we use "Dose Equivalent" H which is related to absorbed dose

$$H = D \times Q$$

(in sieverts [Sv] in 1 J/kg
= 100 rem)

Q is the *Quality Factor* of the radiation
(1 for X-rays, gamma rays and electrons;
10 for neutrons and protons; and 20 for alpha particles)

Biological Damage from Radiation

□ **STRONG** Correlation between ionizing radiation and increased incidence of disease

· both in human and in animal populations

□ Ionizing radiation produces oxidants such as superoxide and hydrogen peroxide

□ Interactions at the cellular and tissue level

· Cytotoxicity from reactive oxides

· DNA strand breaks

· Dose rate and repair

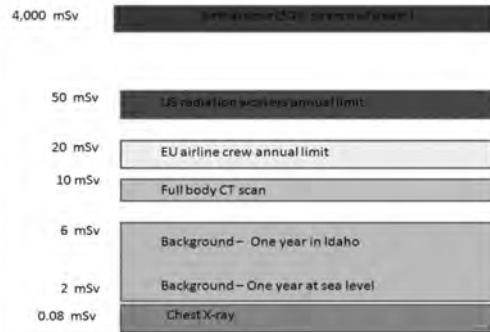
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Study Populations (Health Effects)

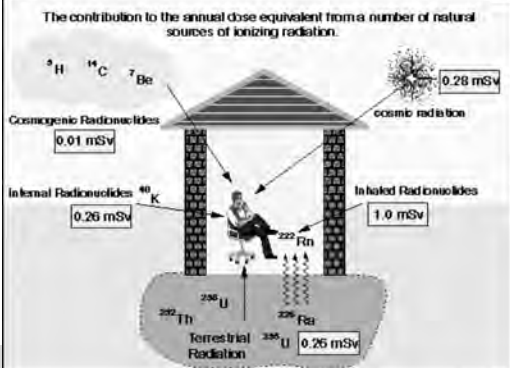
- Survivors of the atomic bombings of Hiroshima and Nagasaki
 - 80,000 survivors plus appropriate control groups
 - Long-term assessment of dosimetry
 - Cancer registry and offspring registries
- Patients receiving radiotherapy
 - Radium doses for ankylosing spondylitis in the UK
 - Radiotherapy for ringworm in U.S. and Israel
 - Fluoroscopic examinations in Canada
- Records of lung cancer for uranium and other miners, who are exposed to radon and its progeny

Lethal, Worker, and Background Doses



source: MIT NSE Nuclear Information Hub


Natural Background Radiation



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Human Contributions to Background



Organizations Involved in Radiation Standards

- ❑ International Commission on Radiological Measurements [Founded 1925]
- ❑ International Commission on Radiological Protection (ICRP) [founded 1928]
- ❑ National Council on Radiation Protection and Measurements (NCRP) [founded 1929]
- ❑ International Atomic Energy Agency (IAEA) [founded 1956]
- ❑ National Academy of Sciences Committee on the Biological Effects of Ionizing Radiation (BEIR)

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Radioactivity and Fukushima

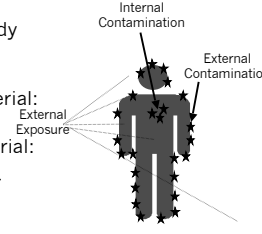
A Perspective on the Health Implications

James P. Seward, MD MPP
Medical Director
Lawrence Livermore National Lab.

This work performed under the auspices of the U.S. Department of Energy by
Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344 LLNL-PRES-478211

Routes of Exposure

- **External Exposure** –
 - Whole-body or partial-body
- **Contamination** –
 - External radioactive material: on the skin
 - Internal radioactive material: inhaled, swallowed, absorbed through skin or wounds



Modified from Health Physics Society

Response to Radiation

- **Deterministic effects:** early or late effects that have dose-effect relationship, *i. e.*, a threshold dose – increase in effects with increasing dose
 - Acute Radiation Syndrome
 - Skin Burns
 - Cataracts
 - Developmental effects (IQ, microcephaly)
- **Stochastic effects:** long-term random or chance effects - relationship, no lower threshold dose for effects
 - Risk of Cancer
 - Heritable Genetic Defects (lab animal studies—not demonstrated in humans)

Modified from REAC/TS

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Acute Radiation Syndrome

- An acute illness that follows a roughly predictable course over a period of time ranging from a few hours to several weeks after exposure to ionizing radiation
- Characterized by the development of groups of signs and symptoms that are manifestations of damage to various tissues and organs by ionizing radiation

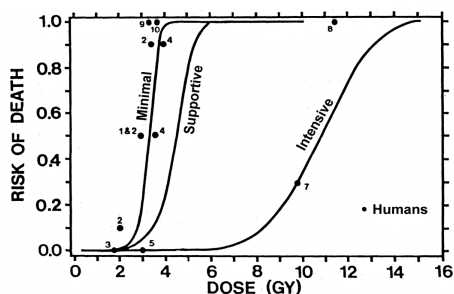
Modified from REAC/TS

Acute Radiation Syndromes

Subclinical	0 - ~100 cGy* (0- ~1 Gy*)
Hematopoietic	~100 - 800 cGy (~1-8 Gy)
Cutaneous / Local	> ~300 cGy (> 3 Gy)
Gastrointestinal	> ~600 cGy (> ~6 Gy)
Respiratory	> ~600 cGy (> ~6 Gy)
CV/CNS	> ~3000 cGy (> ~30 Gy)

*1 Gy = 100 rads 1cGy = 1 rad

Modified from REAC/TS



The LD₅₀ for humans is 3-4 Gy for young adults without medical intervention. EJM, Radiobiology for the Radiologist, 4th Edition, 1994.

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US Regulatory Exposure Limits for Radiation Workers

- Annual Exposure Limit 5 cSv (5 Rem)
- Protect Property for Public Welfare 5 cSv additional
- Emergency (lifesaving/protect public) 25 cSv
- Emergency with full worker understanding >25 cSv
- Organ Dose, including Thyroid 50 cSv

Japan has invoked the emergency standard to allow up to 25 cSv worker exposure at Fukushima

What Do We Know About Worker Protections and Exposures at Fukushima?

- Workforce # ranges from 50 (after onset) to 800 (3/29/11)
- Media refers to a “volunteer workforce”
- Time, Distance, Shielding (including PPE, respirators)
- Rotating workers’ shifts to stay within 25 cSv limit
- Exposure monitoring (direct reading, ion chamber?) and biomonitoring (thyroid scan/whole body scan?)
 - Report of inadequate number of alarmed radiation meters
- KI (age based-presumably)?

Exposure Levels at Fukushima Plant

- Recent dose range at plant gate 0.05 mSv/hr to 0.8 mSv/hr
- Dose rate variable depending on local releases
- Excursions—one up to 40cSv/hour
 - 8x annual dose in 1 hr
 - Plant evacuated at these times
- 3 Workers standing in radioactive puddle 40 min
 - Improper foot protection (boots)- 2 workers
 - 200-500 cSv dose to lower extremity
- ? Typical worker dose during the crisis

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Low-dose Deterministic Effects

Dose	Effects
< 10 rads (cGy)	no detectable difference in exposed vs non-exposed patients
> 12 rads (cGy)	sperm count decreases to minimum by about day 45
20 rads (cGy) whole body	detectable increase in dicentric chromosome aberrations - no clinical signs or symptoms
75-100 rads (cGy) whole body	<ul style="list-style-type: none"> detectable bone marrow depression nausea/vomiting in a small percentage of the population

Modified from REAC/TS

Skin Burn effects begin at approx. 300cGy local exposure. Progress from epilation to erythema, desquamation and ulceration



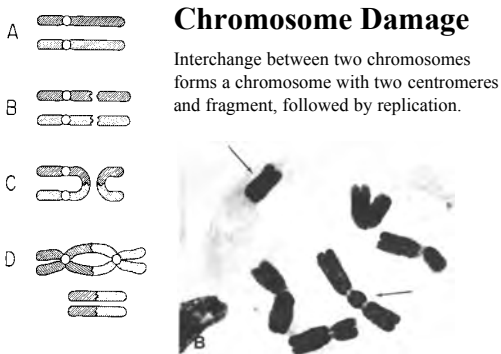
Estimate of Lifetime Excess Risk of Fatal Cancer Due to Short-term Radiation

Short-term ^a Whole-body Dose (rad (Gy))	Excess Lifetime Risk of Fatal Cancer due to Short-term Radiation Exposure ^b (%)
10 (0.1)	1.6
100 (1)	16
200 (2)	32
300 (3)	48 ^c
600 (6)	96 ^d
1,000 (10)	160 ^e

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Fukushima Worker Follow-up

- Dose Assessment—consider cytometric dosimetry
 - Dicentric chromosomes
 - Sensitive at about 20 cGy
- Exam for deterministic effects
 - Some (e.g., cataracts) may take years to evolve
- Appropriate Cancer Screening



Basis for US Nuclear Regulatory Commission 50 mile Fukushima Evacuation Zone

- Modeling of radiation plume and human intakes
- Planning action guide limits:
 - 1cGy whole body dose
 - 5cGy Thyroid dose
 - See: www.nrc.gov
- FDA guidance on KI based on Chernobyl experience
www.fda.gov/downloads/Drugs/GuidanceComplianceRegulatoryInformation/Guidances/ucm080542.pdf

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Potassium Iodide

- Thyroid Protection time dependent
 - 90% reduction I-131 if taken before up to 1 hr. after exposure
 - One dose protects 24 hr.
- Recommended for adults over 40 only if huge (thyroid ablating) exposure
- Special caution and 1 dose only for infants, pregnant, and breastfeeding due to hypothyroidism risk in infant
- Cautions: allergy, GI distress, exacerbation of hyper- and hypothyroidism, some skin conditions

Primary rationale for KI is airborne exposure. Avoidance of significantly contaminated foods/fluids is essential

Potassium Iodide Dose

	Thyroid Exp cGy	KI Dose mg
• Adults >40 years	>500	130
• Adults 18-40	≥ 10	130
• Pregnant/Lactating	≥ 5	130
• Age 3-18 (<70Kg)	≥ 5	65
• 1mo.-3yrs.	≥ 5	32
• Birth-1mo.	≥ 5	16

Radiation Terminology

- Radioactivity
 - Measured in terms of disintegrations
 - Becquerels (Bq) (SI unit)
 - Curies Cu (old term) 1 Cu = 3.7 x 10 E+10 Bq
- Absorbed Dose
 - Gray (Gy) SI unit 1Gy = 100 Rad
 - Rad 1 Rad = 1cGy
- Dose Equivalent (adjusts relative biological effects of different photons/particles using a "quality factor")
 - Sievert (Sv) SI unit 1Sv = 100 REM
 - REM 1Rem = 1cSv

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Questions?

**RADIATION MONITORING
RESOURCES**

California Department of Public Health

- <http://www.arb.ca.gov/carpa/carpa.htm>
- <http://www.cdph.ca.gov/programs/Pages/RHB-RadReport.aspx>

US Environmental Protection Agency

- <http://www.epa.gov/radiation/>

US Food and Drug Administration

- <http://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm249146.htm>
