

Research on the Aftermath of Chernobyl: Have Lessons Been Learned?

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GENERAL COMMENTS

The background of the slide is a photograph of a forest. A dirt path with wooden steps leads up a hill. The trees are mostly bare, suggesting a late autumn or winter setting. The sky is overcast. A red rectangular box with a blue border highlights the subtitle text.

Gilbert W. Beebe Symposium on 30 Years after the Chernobyl Accident

Current and Future Studies on Radiation Health Effects

The National Academies of
SCIENCES • ENGINEERING • MEDICINE

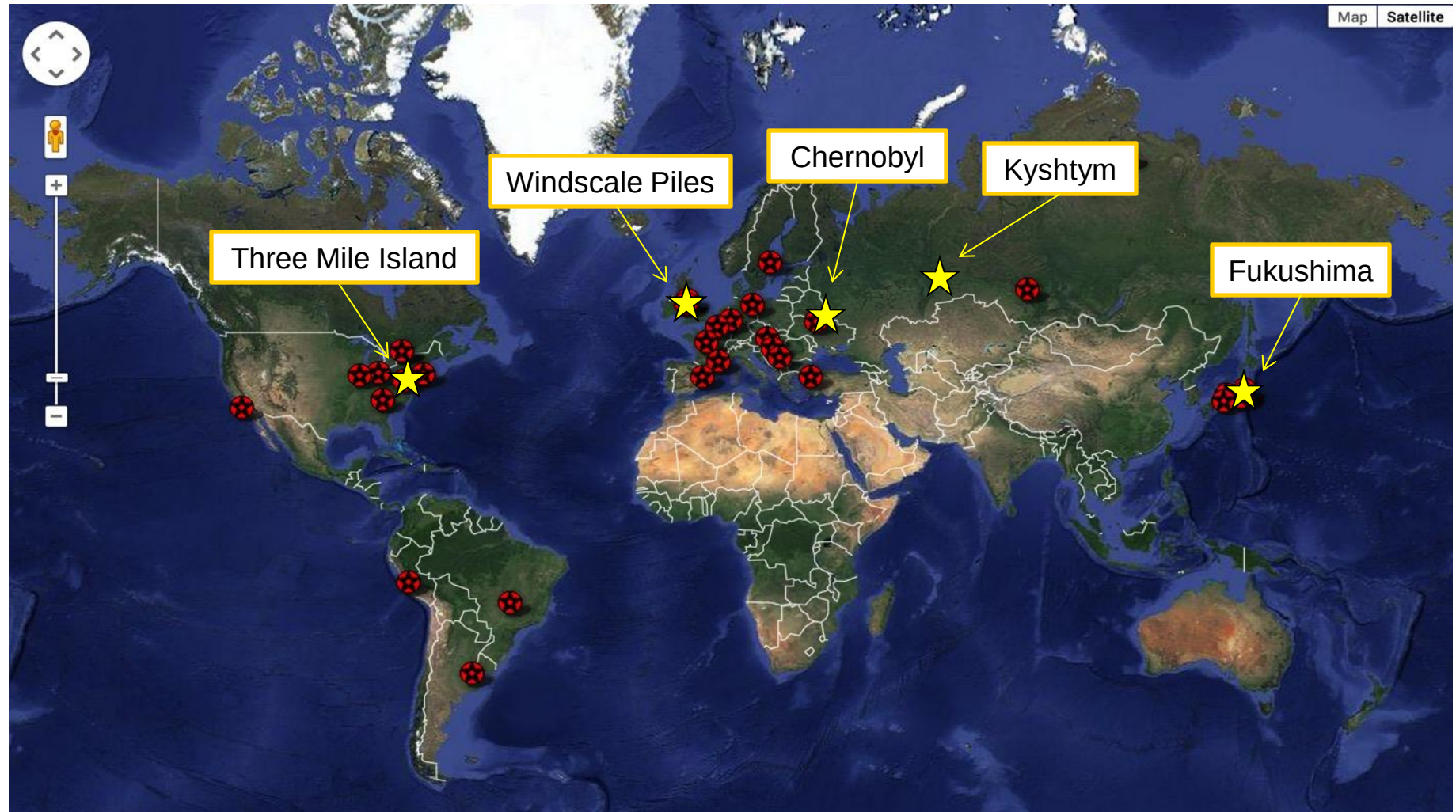
Definition of Health

“A state of complete physical, mental and social well-being and not merely the absence of disease or infirmity”

— World Health Organization

What are “radiation health effects”?

Major Nuclear Disasters



<http://www.theguardian.com/news/datablog/2011/mar/14/nuclear-power-plant-accidents-list-rank#data>;

Hasegawa A, et al. Health effects of radiation and other health problems in the aftermath of nuclear accidents, with an emphasis on Fukushima. *Lancet*. 2015 Aug 1;386:479-88.

Table 1: Past severe nuclear accidents (International Nuclear and Radiological Event Scale level 5 or higher)

	Kyshtym ^{10,11}	Windscale Piles ^{11,12}	Three Mile Island ^{13,14,15,16}	Chernobyl ^{4,5}	Fukushima ^{6,17-19}
Location	Kyshtym, Chelyabinsk Oblast, Russia (then USSR)	Sellafield, UK	Dauphin county, PA, USA	Chernobyl, Ukraine (then USSR)	Fukushima, Japan
Date	Sept 29, 1957	Oct 10, 1957	March 28, 1979	April 26, 1986	March 11, 2011
Type of accident	Chemical explosion of containment tank of liquid radioactive wastes at military installation	Fire of nuclear reactor at military installation designed to produce plutonium	Partial core melt at civilian nuclear reactor	Core explosion and fire at civilian nuclear reactor	Core melt-through; three reactor cores damaged; three reactor buildings damaged by hydrogen explosions
Are findings transferrable? Externally valid?					
Dose estimates	Average effective dose of residents: 170 mSv (preceding evacuation); 520 mSv (effective dose equivalent)	Maximum estimated thyroid doses of residents: the order of 10 mGy (adults); 100 mGy (children)	Maximum effective dose: 40 mSv (emergency worker); effective dose of residents living within 80 km: 0.015 mSv (average); 0.85 mSv (maximum)	Workers with acute radiation syndrome: <2.1 Gy (41 people); 2.2-4.1 Gy (50 people); 4.2-6.4 Gy (22 people); 6.5-16.0 Gy (21 people); average thyroid dose of residents: 349 mGy (adult evacuees); 1548 mGy (preschool children evacuees); 138 mGy (adults in contaminated areas); 449 mGy (preschool children in contaminated areas)	Maximum effective dose: 678 mSv (emergency worker); maximum thyroid dose: 12 Gy (emergency worker); maximum effective dose of residents: 25 mSv (external); maximum average thyroid dose of infants in the most affected district: 80 mGy
Implications	Restriction of information about accident by government	Poor preparedness before accident; milk distribution banned 10 km north of Windscale Works to 20 km to the south	Scarcity of information about nuclear power plant condition and evacuation plan; no effective plan for hospital and nursing care facility evacuation	Restriction of information about accident by government; delay in implementation of public protection; long-term psychological issues	Severe health effects of evacuation and relocation of hospital inpatients and elderly people needing nursing care; psychosocial issues after accident; poor risk communication
USSR=Union of Soviet Socialist Republics.					

How Can a Nuclear Disaster Harm People?

- Acute consequences
 - High-level exposure → Radiation Sickness
 - Psychological stress → Anxiety/Depression
- Long-term consequences
 - Radiation exposure
 - Psychological/Social Stress

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graph LR; A[Radiation exposure] --> B[Cancer Risk]; A --> C[Cardiovascular disease risk]; D[Psychological/Social Stress] --> B; D --> C; D --> E[PTSD]; D --> F[Depression/Anxiety];
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 - Cancer Risk
 - Cardiovascular disease risk
 - PTSD
 - Depression/Anxiety

THE LANCET

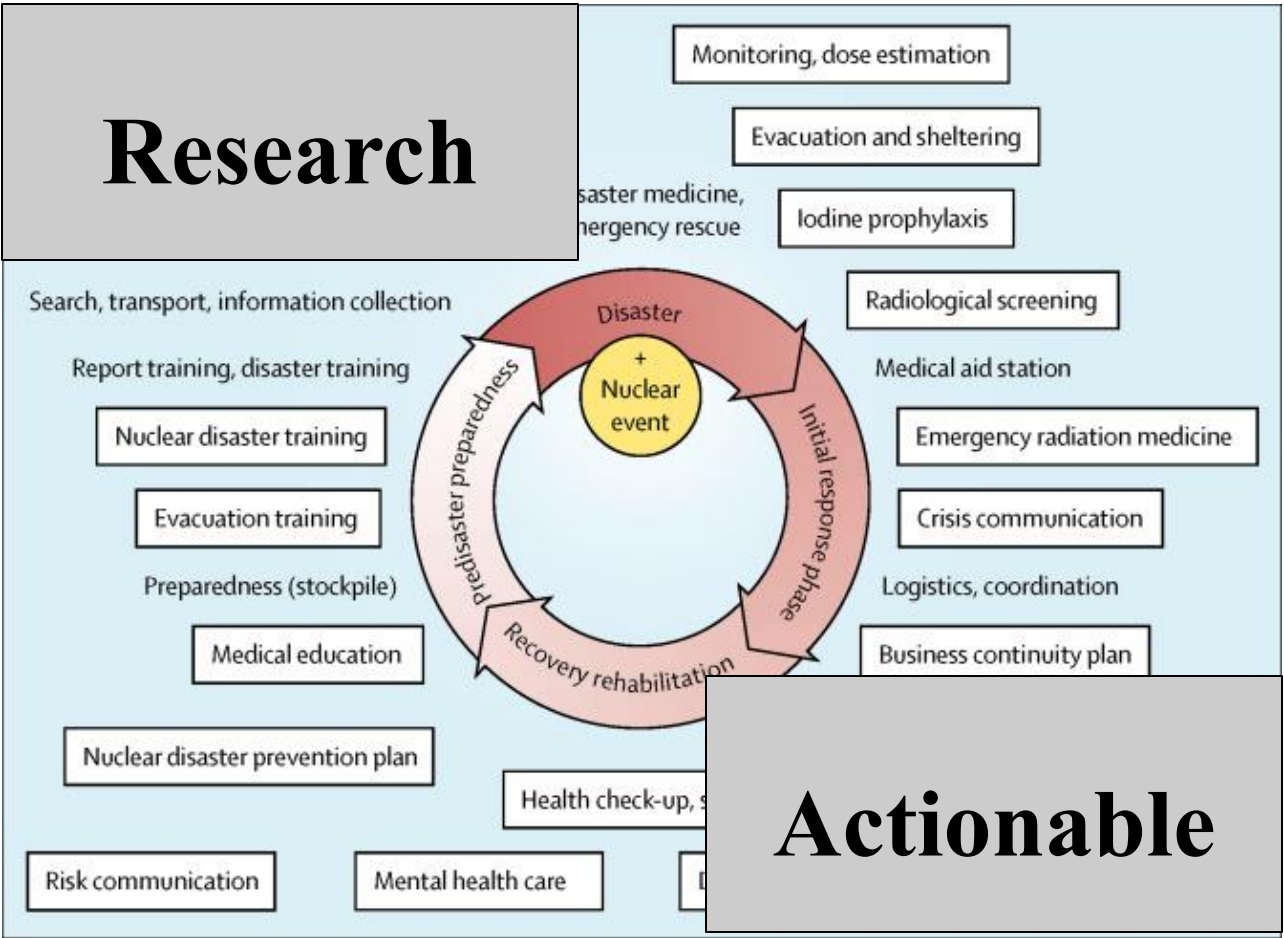
From Hiroshima and Nagasaki to Fukushima 3 Series

Nuclear disasters and health: lessons learned, challenges, and proposals

Ohtsuru, Akira et. al

Figure 2: Nuclear disaster cycle

Medical issues in a compound disaster. Boxes refer to measures specifically needed in a nuclear disaster, those not in boxes are measures common to any large-scale disasters.





disasters



In the news



After natural disasters, elderly survivors show cognitive decline

Ars Technica - 1 hour ago
Recovery from a life-disrupting **disaster** presents challenges to everyone. But the elderly ...

California Inc.: Top state court to hear case on disaster insurance
Los Angeles Times - 7 hours ago

Move it Monday: The top 5 diet disasters
Siouxland Matters - 4 hours ago

More news for disasters

Disasters - Wiley Online Library
onlinelibrary.wiley.com/journal/10.1111/(ISSN)1467-7717 ▾ John Wiley & Sons ▾
Disaster risk, climate change and international development: scope for, and ... **Disasters** is available to qualifying institutions for free through the HINARI,AGORA ...

Disasters - All Issues - Wiley Online Library
onlinelibrary.wiley.com > ... > Disasters ▾ John Wiley & Sons ▾
2016 - Volume 40 **Disasters** · 2015 - Volume 39 **Disasters** · 2014 - Volume 38 **Disasters** · 2013 - Volume 37 **Disasters** · 2012 - Volume 36 **Disasters** · 2011 ...

Images for disasters

Report images



About 119,000,000 results (0.46 seconds)

10 Deadly Natural Disasters Caught on Video - YouTube



https://www.youtube.com/watch?v=zQYe3ngG6qs ▾
Jun 27, 2015 - Uploaded by TheRichest
Top 10 horrible natural **disasters** that affected the world. These terrible acts of nature that were caught on ...

Disasters | ReliefWeb

reliefweb.int/disasters ▾ ReliefWeb ▾
Oct 19, 2016 - ReliefWeb **disaster** pages provide an overview of the situation and situation reports, news and press releases, assessments, evaluations, ...

Natural Disasters News -- ScienceDaily

https://www.sciencedaily.com/news/earth_climate/natural_disasters/ ▾ Science Daily ▾
Natural Disaster News and Research. Earthquakes, volcanic eruptions, landslides, tsunamis and other natural **disasters**. Research past events, review ...

The Red Cross' Secret Disaster - ProPublica

https://www.propublica.org/article/the-red-cross-secret-disaster
Americans did what they so often do after **disasters**. They sent hundreds of millions of dollars to the Red Cross, confident their money would ...

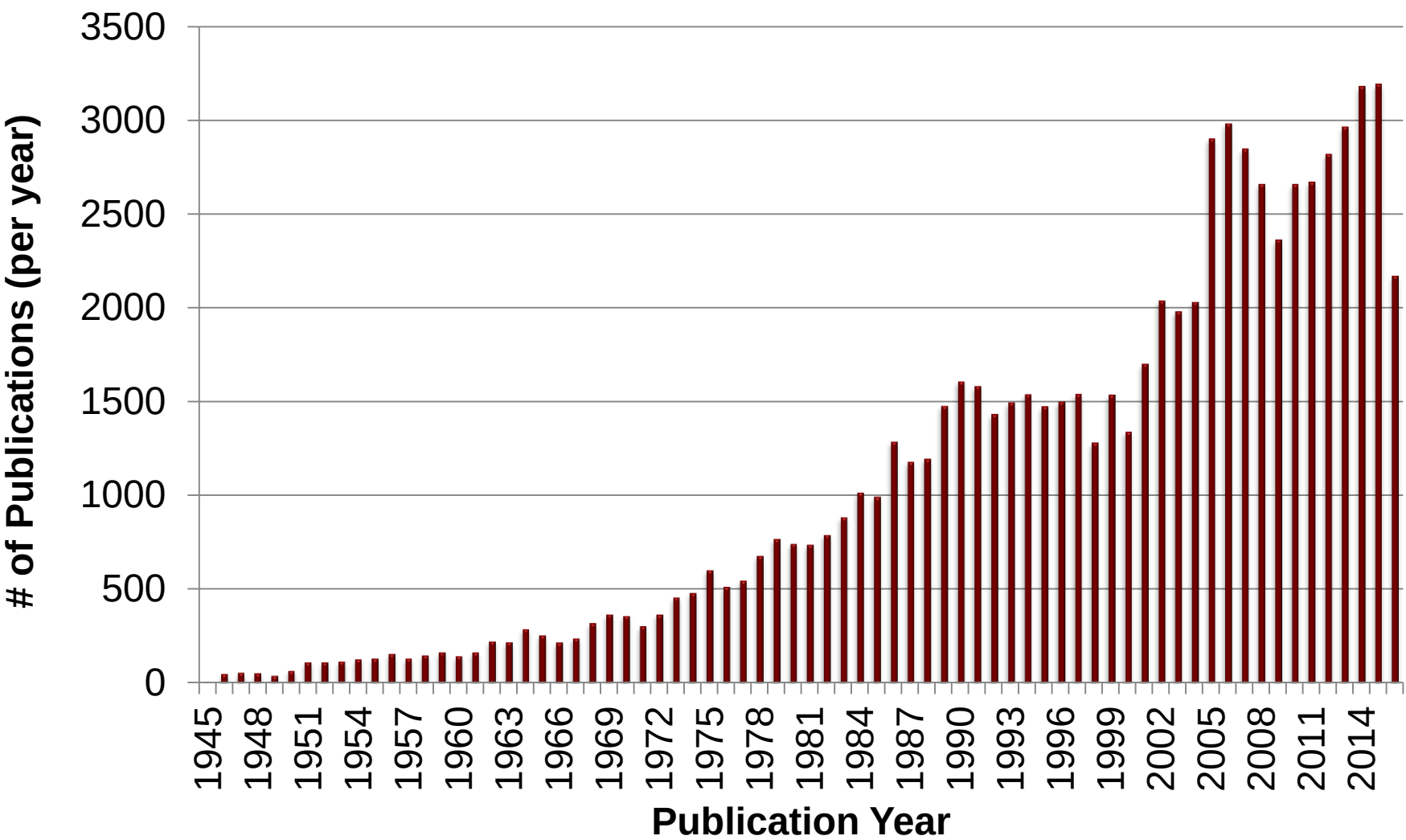
Planetary disasters: It could happen one night : Nature News ...

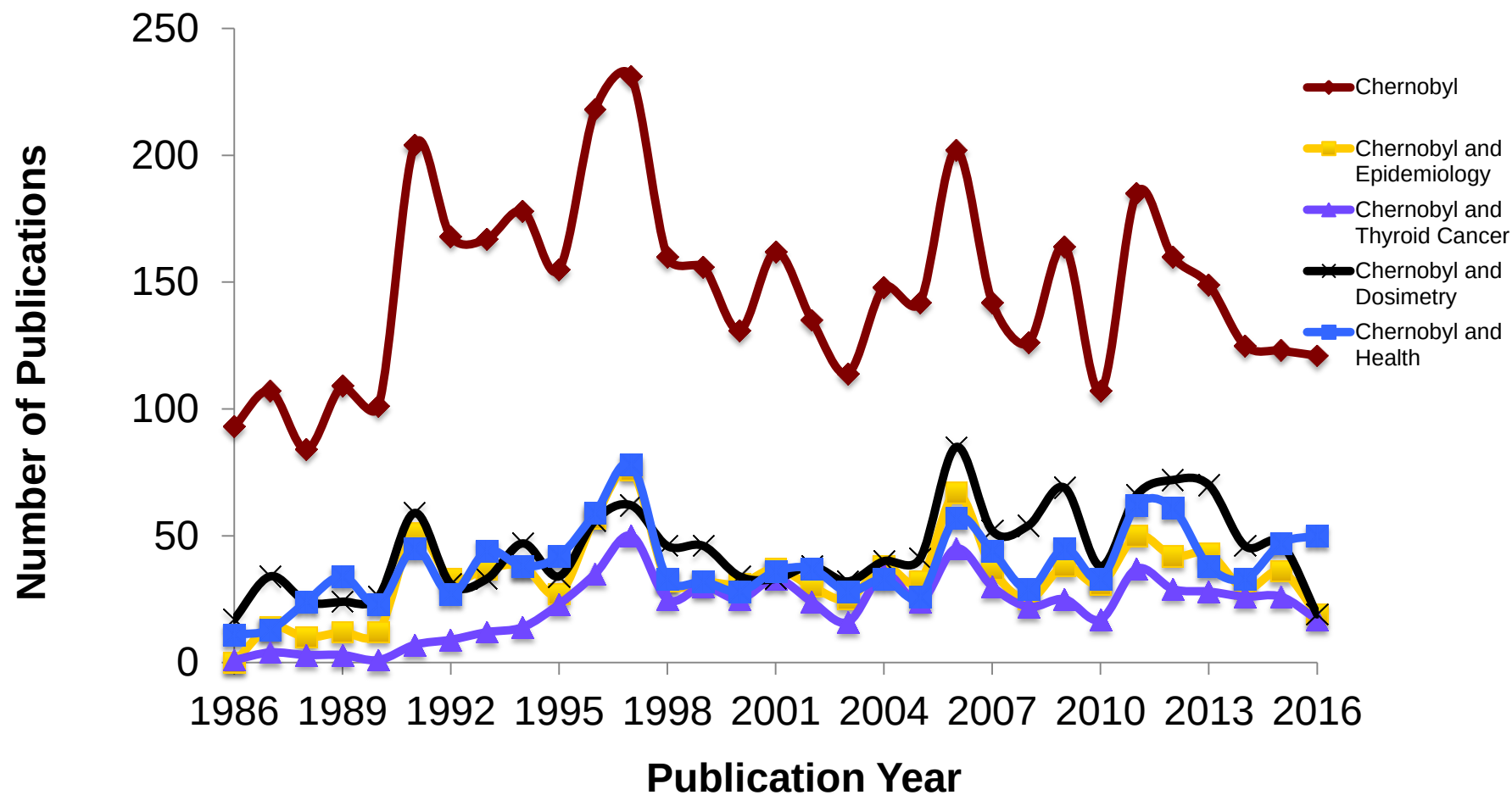
www.nature.com/news/planetary-disasters-it-could-happen-one-night-1.12174
Planetary **disasters**: It could happen one night. Catastrophes from the past will strike again — we just do not know when. Nicola Jones.

The Mothers of All Disasters - The Atlantic

www.theatlantic.com/national/archive/2015/09/the-disaster-next-time/403063/
The biggest **disasters** seem so far out of the range of the normal possibilities of daily life that it's nearly impossible to even envision the scale of ...

PubMed Citation Analysis: ‘Disaster’



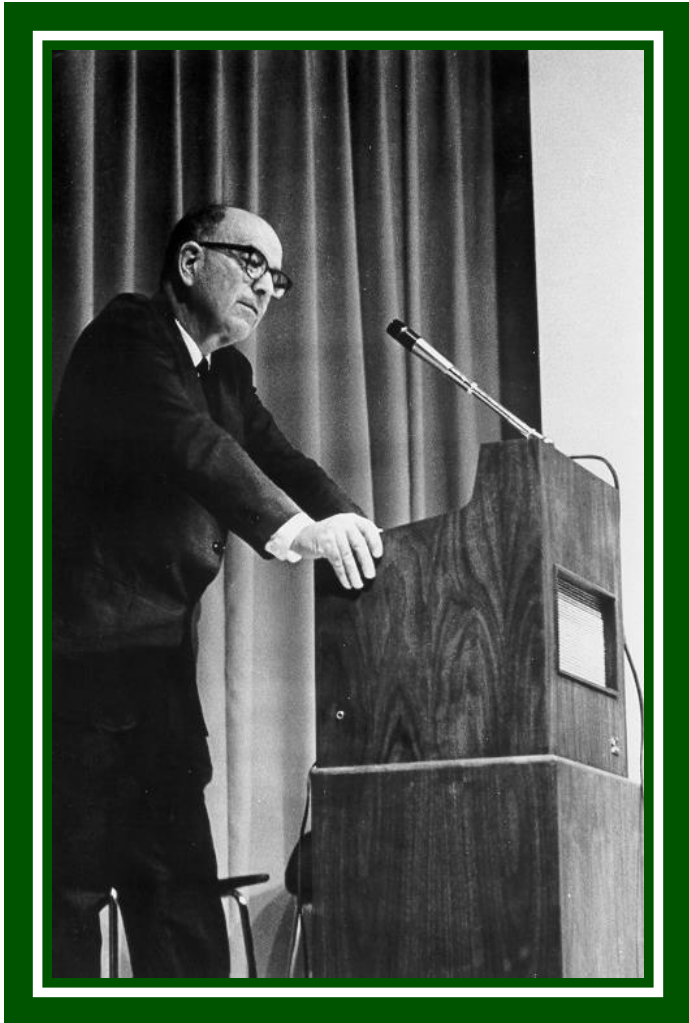


WHY DO STUDIES?

Apologies to Donald Rumsfeld

- “Known knowns”
 - Refining risk estimates
- “Known unknowns”
 - Hazard identification: new outcomes
 - Completing understanding of dose-response
- “Unknown unknowns”
 - Overturning strong priors
 - Finding surprises

Alexander Langmuir, MD, MPH



1912 – 1993

“Surveillance, when applied to a disease, means the continued watchfulness over the distribution and trends of incidence through the systematic collection, consolidation and evaluation of morbidity and mortality reports and other relevant data.”

Source: The New England Journal of Medicine 1963;268(4):182-192

Research or Surveillance

Research

- Data gathering to advance knowledge
- Implement to take advantage of opportunity to generate data
- Results may/may not benefit those exposed

Surveillance

- Data gathering to track events for decision-making
- Can overlap with research
- Sentinel events may be of interest

Why *research* after a nuclear disaster

- Address unanswered questions
 - Risks of specific radionuclides
 - Non-stochastic effects
 - Neuropsychological consequences
- Refine risk estimates for decision-making
- Communicate with stakeholder groups
- Build resources for future research
 - Biorepositories

Why surveillance after a nuclear disaster?

- Watch for surprises
- Identify problems needing intervention
- Evaluate the effectiveness of interventions
- Have data to communicate to all stakeholders

What have we learned over the 30 years (that is new)?

- Thyroid cancer in children story
- CLL in liquidators
- Cataract at lower doses than expected
- Lasting neuropsychological consequences

SOME LESSONS LEARNED

Dosimetry

Commentary

All EHP content is accessible to individuals with disabilities. A fully accessible (Section 508–compliant) HTML version of this article is available at <http://dx.doi.org/10.1289/ehp.1307120>.

Guidelines for Exposure Assessment in Health Risk Studies Following a Nuclear Reactor Accident

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BACKGROUND: Worldwide concerns regarding health effects after the Chernobyl and Fukushima nuclear power plant accidents indicate a clear need to identify short- and long-term health impacts that might result from accidents in the future. Fundamental to addressing this problem are reliable and accurate radiation dose estimates for the affected populations. The available guidance for activities following nuclear accidents is limited with regard to strategies for dose assessment in health risk studies.

OBJECTIVES: Here we propose a comprehensive systematic approach to estimating radiation doses for the evaluation of health risks resulting from a nuclear power plant accident, reflected in a set of seven guidelines.

DISCUSSION: Four major nuclear reactor accidents have occurred during the history of nuclear power production. The circumstances leading to these accidents were varied, as were the magnitude of the releases of radioactive materials, the pathways by which persons were exposed, the data collected afterward, and the lifestyle factors and dietary consumption that played an important role in the associated radiation exposure of the affected populations. Accidents involving nuclear reactors may occur in the future under a variety of conditions. The guidelines we recommend here are intended to facilitate obtaining reliable dose estimations for a range of different exposure conditions. We recognize that full implementation of the proposed approach may not always be feasible because of other priorities during the nuclear accident emergency and because of limited resources in manpower and equipment.

CONCLUSIONS: The proposed approach can serve as a basis to optimize the value of radiation dose reconstruction following a nuclear reactor accident.

CITATION: Bouville A, Linet MS, Hatch M, Mabuchi K, Simon SL. 2014. Guidelines for exposure assessment in health risk studies following a nuclear reactor accident. *Environ Health Perspect* 122:1–5; <http://dx.doi.org/10.1289/ehp.1307120>

Epidemiologic studies are usually undertaken several years after the accident to allow time for the health consequences to be expressed, are based on the analysis of observed adverse health effects, and seek to ascertain risks of these adverse effects in comparison with the background or baseline rates. Such investigations typically involve the collection of exposure and outcome data for the study participants and require individual dose estimation.

The basic difference in these two types of studies is that risk projections generate expected rates of disease whereas epidemiologic studies generate observed rates of disease. In this commentary, we discuss dose assessment and data collection guidelines to support both types of studies.

Four past reactor accidents have each resulted in irreparable damages to the power plant and in substantial radiation exposures involving $\geq 1,000$ people as a consequence of the releases of radioactive materials into the environment. The first of those accidents took place in 1957 at Windscale in the United Kingdom and was caused by a fire in the reactor, which was mainly used for the

Table 1. Value of applying guidelines to the different types of health risk studies.

Guideline	Strategy	Value to risk projection studies		Value to epidemiologic studies
		Early phase	Late phase	
1	Creation of a roster of exposed persons	Unnecessary	Unnecessary	Essential
2	Collection of individual-based radiation measurements	Useful	Useful	Highly useful
3	Collection of personal information on exposed persons	Unnecessary	Unnecessary	Highly useful
4	Collection of data on radiation field	Essential	Essential	Essential
5	Calculation of realistic unbiased doses	Useful	Essential	Essential
6	Validation of dose estimates	Unnecessary	Useful	Highly useful
7	Evaluation of uncertainties of dose estimates	Unnecessary	Highly useful	Highly useful

Source: Bouville et al. Environmental Health Perspectives 2014

Psychological Distress and Radiation Levels The Fukushima Health Management Survey

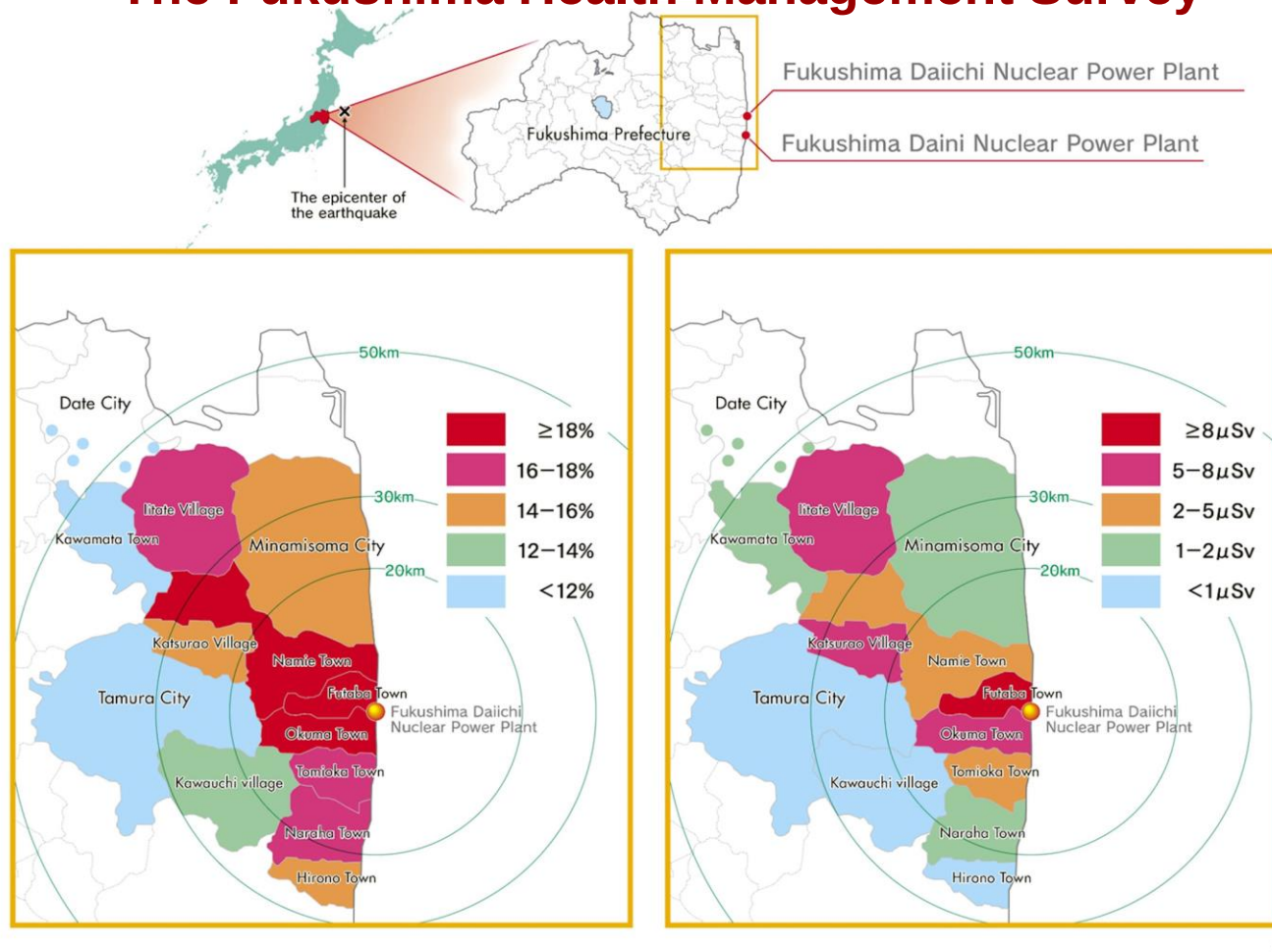


Fig 2. The distribution of psychological distress in evacuation zone (A) and environmental radiation levels ($\mu\text{Sv/h}$) in evacuation zone (B). The distribution of psychological distress showed pattern similar to the environmental radiation levels on a prefectural map of Fukushima (based on the levels reported in a local newspaper Fukushima Minpo dated January 20, 2012). Spearman's rank correlation showed that the proportion of those in the evacuation zone who scored ≥ 13 on the K6 was significantly highly correlated with the environmental radiation levels ($r = 0.768, p = 0.002$). The 18% in (A) means the area where more than 18% of the participants scored >13 on the K6, and $>8 \mu\text{Sv/h}$ in (B) means the area where $>8 \mu\text{Sv/h}$ was recorded. Original maps were created by tracing copyright-free materials (<http://kage-design.com/wp/?p=1061> and <http://www.civilcom.co.jp/library/WhiteMapJapan/#07>) and then drawing the content using Adobe Illustrator CS6 (Adobe Systems Inc., San Jose, CA).

Analytical Methods

- Propagation of uncertainty
- Addressing measurement error
 - Validation studies
 - Models for ME correction
- New approaches for dose-response modeling

Cancer Risks

- We have strong evidence on risks for some cancers (strong priors established-- CLL for example).
- We can always refine risk estimates
- Surprises happen
- Some new questions will inevitably arise, but what populations for new research?
- When should studies be extended to “get the full picture”?

Non-Cancer Risks

- ARS: can we do better with data capture and follow-up?
- CVD: a very important contributor to disease burden but MRIN
- In utero exposures: complex territory and of great potential importance; what next?
- Cataract: dose-response and risks at lower end of dose range

Neuropsychological Consequences

- The "orphan" of adverse effects
- Need to use community-based methods
- Need to approach with multi-level models that include individuals and communities
- Research needs to be tied to interventions and evaluation

INFLUENCE OF CHERNOBYL ON FUKUSHIMA?

Challenges

Chernobyl

- Initially:
 - True impact of the disaster
 - Clean-up activities: minimizing radiation exposure
 - Evacuation of people living in the 30km exclusion zone
- Three decades later:
 - Poor mental and physical health
 - Impact of resettlement
 - Economic burden
 - Containment of radiation (sarcophagus)

Fukushima

- Initially:
 - Accessing the plant
 - Controlling temperature
 - Dealing with multiple disasters at plant and offsite
- Five years later:
 - Management of contaminated water
 - Monitoring of seawater radioactivity
 - Some areas still not accessible due to radiation
 - Displaced populations
 - Medical screening

From Chernobyl to Fukushima

- Broad population survey implemented by Fukushima Medical University
- Thyroid cancer screening implemented for at-risk population
- Worker cohort study underway involving medical screening
- Dosimetry estimation

LOOKING TO THE FUTURE

New Opportunities

- 21st century science
 - Biomarkers of dose
 - Biobanks
 - Genomics and other “omics”
- Pooling of data
- Multidisciplinary approaches supporting risk assessment

original manuscript

**Carcinogenesis Advance Access published
October 26, 2016**

Integration of a radiation biomarker into modeling of thyroid carcinogenesis and post- Chernobyl risk assessment

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Logistics

- Tissue banks
- Data sharing
- Strategic agendas
- Funding
- Stakeholder engagement and communication



Research Projects – 2010 – 2019

Approved projects

EpiRadBio

Molecular specificities of radiation-induced thyroid tumors

EpiRadBio – Validation of radiation-associated gain of chromosome band 7q11

A Sequence-based Approach to Identify Genetic Determinants of Tumorigenesis in Radiation-Induced Pediatric Papillary Thyroid Carcinomas

EpiRadBio – integrative analysis of molecular data

Validation of the gene signature differentiating exposed from non-exposed PTCs, obtained in the Genrisk-T project (no.: 036495) with an independent QPCR method

A detailed study of the somatic genomics of radiation induced thyroid cancer

Assessing the impact of radiation exposure on the development of medullary thyroid carcinoma

Anaplastic lymphoma kinase (ALK) – rearrangements in radiation-induced papillary thyroid carcinomas: a study on post Chernobyl tissue samples

Comprehensive Genomic Characterization of Radiation-Related Thyroid Cancer in Ukraine

Project reference number: 001/2011

Principal Investigator: Dr K Unger, Helmholtz Centre, Munich, Germany

Email: unger@helmholtz-muenchen.de

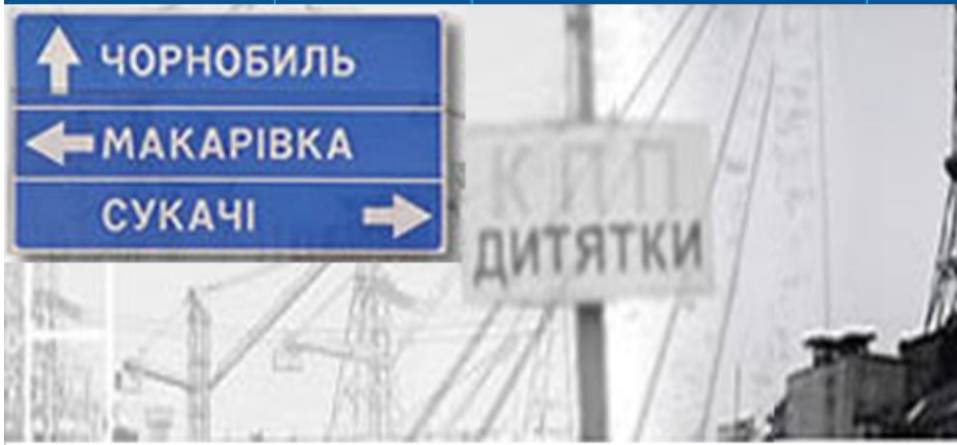
EpiRadiBio

Source: <http://www.chernobyltissuebank.com/research-projects-2010-2019.htm>



Source: <http://arch.iarc.fr/>

ORGANISATION	WHO'S WHO	TERMS OF REFERENCE	DOCUMENTS	REFERENCES	LINKS	MEMBERS AREA	CONTACT
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ARCH is a European Commission FP7 Project to develop a study on the health consequences of the Chernobyl accident



The Chernobyl accident led to the most comprehensive study of the health consequences of nuclear accidents apart from the atomic bombings in Japan. The study has been comprehensively studied. In some countries, the study is very informative; in others, little work has been done. The study is mainly based on whole body exposures and not on local exposures, but of great public concern.

Questions relate to the choice of models for the estimation of risks from external high internal radiation. Questions also concern the estimation of risks from low levels of radiation. Chernobyl has an opportunity to answer these questions,

<http://arch.iarc.fr/>



Strategic Research Agenda

The Health Consequences of the Chernobyl Accident

Planning Prospectively

- Are there templates for considering research/surveillance in any future accident situations?
- Dosimetry issues have been considered
- Is broader planning needed?
- Draw on experiences with other disaster situations?
- Stakeholder roles?

**There will be a 40th Anniversary
Symposium**

