The international sign for radioactivity
Ionizing Radiation Types

- Alpha particles \((^4\text{He}^{++})\)
- Beta particles \((e^+ \text{ and } e^-)\)
- Gamma-rays \((\gamma)\)
- Neutrons \((n)\)

The international sign for radioactivity
Nuclear Radiation

Atomic decay by Alpha and Beta radiation causes atomic transmutation. Gamma radiation does not transmutate the atom, it changes its energy.
Health Effects of Ionizing Radiation
Ionizing Radiation Effects on Cells

Ionization Energy ~ few eV ~ $10^{-18}$ J

$\alpha,\beta,\gamma$ radiation can ionize atoms which break chemical bonds and damage molecules in cells:

1. Interferes with cell reproduction
2. Destruction of cell’s function or destruction of cell itself.

It has the greatest effect on cells that are rapidly reproducing because they do not have time to repair the damage:

1. Fetus, infants, children (also in animals and plants)
2. Cancerous cells

Ionizing Radiation can cause cancer or kill cancer!
Ionizing EM Radiation: UV, Xray & Gamma

Energy to ionize atom or molecule: 10-1000eV
Gamma Radiation:

*Above a few keV are Highly Penetrating*

**High Intensity:** If you were very near a nuclear device as it exploded, an intense pulse of gamma rays would destroy the functioning of your nervous system and almost immediately afterwards cause intense heating throughout your body, sufficient to vaporize you in about a microsecond.

**Lower Intensity:** Gamma-rays injure cells by creating high-energy electrons throughout the body, charged particles which can disrupt any chemical bond they happen to encounter as they fly along. Electrons (positrons) are produced by the photo-electric effect, Compton scattering or pair-production.
Gamma Ray Knife
Astrophysics, abstract astro-ph/0512013

From: Douglas Galante [view email]
Date (v1): Thu, 1 Dec 2005 03:28:14 GMT  (229kb)
Date (revised v2): Wed, 8 Nov 2006 19:45:45 GMT  (130kb)

Biological Effects of Gamma-Ray Bursts: distances for severe damage on the biota

Authors: Douglas Galante, Jorge Ernesto Horvath
Comments: 32 pages, 3 figures, accepted for publication by the International Journal of Astrobiology with minor changes

We present in this work a unified, quantitative synthesis of analytical and numerical calculations of the effects that could be caused on Earth by a Gamma-Ray Burst (GRB), considering atmospheric and biological implications. The main effects of the illumination by a GRB are classified in four distinct ones and analyzed separately, namely: direct gamma Flash, UV Flash, Ozone Layer Depletion and Cosmic Rays. The effectiveness of each of these effects is compared and distances for significant biological damage are given for each one. We find that the first three effects have potential to cause global environmental changes and biospheric damages, even if the source is located at Galactic distances or even farther (up to 150 kpc, about five times the Galactic diameter of 30 kpc). Instead, cosmic rays would only be a serious threat for close sources (on the order of a few pc). As a concrete application from a well-recorded event, the effects on the biosphere of an event identical to the giant flare of SGR 1806-20 on Dec 27, 2004 have been calculated. In spite of not being a classical GRB, most of the parameters of this recent flare are quite well-known and have been used as a calibration for our study. We find that a giant flare impinging on Earth is not a threat for life in all practical situations, mainly because it is not as energetic, in spite of being much more frequent than GRBs, unless the source happens to be extremely close.

Full-text: PDF only

References and citations for this submission:
CSLAP: Crossref (used to check how many people cited this paper)
Ionizing Radiation: neutrons

Because of their tremendous penetrating ability, neutrons can be very damaging to the human body. When neutrons strike atoms of elements that are not fissionable, they can render them radioactive by changing their atomic structure. For example, in a building near a neutron bomb explosion, the neutrons can change stable cobalt in the steel girders to cobalt 60, an emitter of highly penetrating gamma radiation.
Exposure vs Dose

“Exposure" refers to how much radioactive material entered a person's body. Not all radiation entering the body stays there. Much of it is flushed out through breathing or along with other waste products.

"Dose" refers to the amount of radioactive energy that is actually absorbed by tissues in the body. For instance, about a third of the iodine-131 entering the body is absorbed by the thyroid. Traces of it are absorbed by other body organs. The rest is flushed from the body.
Radiation Dose

Radiation dose unit (rad) : $1 \text{ r} = 0.01 \text{ J/kg}$

The biological effect depends on the type of radiation and body part:
RBE: Relative biological effectiveness

**Roentgen Equivalent Man: rem = rad x RBE**

<table>
<thead>
<tr>
<th>Type of energy of radiation</th>
<th>RBE</th>
</tr>
</thead>
<tbody>
<tr>
<td>X rays</td>
<td>1</td>
</tr>
<tr>
<td>Gamma rays</td>
<td>1</td>
</tr>
<tr>
<td>Beta rays $&gt; 30\text{KeV}$</td>
<td>1</td>
</tr>
<tr>
<td>Beta rays $&lt; 30\text{ KeV}$</td>
<td>1.7</td>
</tr>
<tr>
<td>Neutrons, slow</td>
<td>2-5</td>
</tr>
<tr>
<td>Neutrons, fast</td>
<td>10 (body) 30 (eyes)</td>
</tr>
<tr>
<td>Alpha Rays</td>
<td>10-20</td>
</tr>
</tbody>
</table>
### Table 30.3 Dose delivered in less than one day

**Immediate Effects of Radiation (Adults, Whole Body, Single Exposure)**

<table>
<thead>
<tr>
<th>Dose in rem†</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–10</td>
<td>No observable effect. Possible latent effects (cancer)</td>
</tr>
<tr>
<td>10–100</td>
<td>Slight to moderate decrease in white blood cell counts.</td>
</tr>
<tr>
<td>35, 50</td>
<td>Temporary sterility; 35 for women, 50 for men.</td>
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<td>Significant reduction in blood cell counts, brief nausea and vomiting. Rarely fatal.</td>
</tr>
<tr>
<td>200–500</td>
<td>Nausea, vomiting, hair loss, severe blood damage, hemorrhage, fatalities.</td>
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<tr>
<td>450</td>
<td>LD50/30. Lethal to 50% so exposed in 30 days if untreated.</td>
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<tr>
<td>500–2000</td>
<td>Worst effects due to malfunction of small intestine and blood systems. Limited survival.</td>
</tr>
<tr>
<td>&gt;2000</td>
<td>Fatal within hours due to collapse of central nervous system.</td>
</tr>
</tbody>
</table>

† Divide by 100 to obtain dose in Sv.

Total Average US Background Level Radiation: 382 mrem

Other Units

1 Gray (Gy) = 1 J/kg = 100 rad

1 sievert (Sv) = 100 rem
Dose: Acute vs Chronic Dose

An acute radiation dose is defined as a large dose (10 rad or greater, to the whole body) delivered during a short period of time (on the order of a few days at the most). If large enough, it may result in effects which are observable within a period of hours to weeks.

A chronic dose is a relatively small amount of radiation received over a long period of time. The body is better equipped to tolerate a chronic dose than an acute dose. The body has time to repair damage because a smaller percentage of the cells need repair at any given time. The body also has time to replace dead or non-functioning cells with new, healthy cells. This is the type of dose received as occupational exposure.
Threshold vs Non-Threshold FX

**Threshold effects** occur with acute exposure when levels of radiation exposure are tens, hundreds, or thousands of times higher than background, and usually when the exposure is over a very short time, such as a few minutes.

**Non-threshold effects** can occur at any level of radiation exposure, but the risk of harmful health effects generally increases with the amount of radiation absorbed. The most studied non-threshold effect is cancer. These studies are somewhat complicated by the facts that (1) not all cancers are caused by radiation, (2) exposure to a particular dose may cause cancer in one person but not another, and (3) the cancer often doesn't appear until many years after the exposure to radiation. It is currently impossible to determine which cancers are caused by radiation and which are caused by other carcinogens in our environment.
Immediate vs Delayed FX

Immediate effects are due to an acute (short term) exposure: a large exposure that takes place over a short period of time.

Delayed effects are due to latency period of cancer and disease where a health effect of radiation exposure may not become apparent for months, years or several decades after the exposure occurs. Leukemia has a latency period of 2 years, other cancers, 15 or more. If a sperm or egg are damaged then the latency period can be generations.
LINEAR HYPOTHESIS
A model of radiation health effects based on the theory that the damage per rad is proportional. That is, the number of induced cancers is directly proportional to the dose of radiation delivered, down to the lowest possible dose.

NO THRESHOLD PREMISE
This is the premise that there is no level below which exposure to radiation does not increase the risk of cancer. Any dose of ionizing radiation can increase the risk of developing cancer in many organs and tissues of the body.
Low Dose & Cancer

• It has been estimated that the radioactive fallout from the nuclear accident at Chernobyl in 1986 will cause an increase of 17,000 cancers over the lifetime of people living in the Northern Hemisphere.

• Large though this estimate seems, it is dwarfed by the 513 million cancer deaths that will occur anyway in this population.

• This is why it is difficult to quantify the dangers of low doses.

• Some scientists (very few) claim that low doses are GOOD for adults because they keep the cells ‘in shape’ to repair themselves.
Increased Cancer Risk: Bomb Victims

The increased risk of various types of cancer has been studied extensively among the victims of the Hiroshima and Nagasaki nuclear bombs. The study of 120,000 Japanese has led to the relative risk factors shown. The risk appears to be linear with dose. The dose at 1000 meters at Hiroshima is estimated at 4 grays.

1 gray = 100 rads


Radiation units

HyperPhysics***** Nuclear
Background Radiation: ~300 mrem/year

• Sources are UV radiation and cosmic particles, radium, radon, potassium 40, carbon 12 present in rocks, air, and our own body cells.

• Exposure to Natural Radiation induced mutations may have contributed to our evolutionary process. Most geneticists believe that humanity has reached an evolutionary peak in beneficial mutations caused by natural radiation that the species can undergo. Thus any further mutations are detrimental, causing disease and deformity.

• Although the exact percent is unknown, background radiation is thought to be responsible for a portion of all cancers and genetic disorders.
Sample Problem

Plutonium-239 decays by alpha emission with energy 6.02 MeV. If you inhale 1 milligram of plutonium and it effects 1.00 kg of your lung, what would be your dose in rem if 50% of the energy is absorbed? What biological effect would that have on your body? Assume the lowest RBE for alpha particles.

\[
\text{dose} = \frac{\text{energy}}{\text{mass effected}} = \frac{\# \text{decays} \times \text{Energy/decay}}{\text{mass of lung}}
\]

\[
\# \text{decays} = \text{Activity} = A = \lambda N = \frac{0.693}{t_{1/2}} N
\]

**Number Particles:**

\[
N = m \frac{N_A}{M}
\]

(M is the atomic mass which is also the number of moles in 1 gram. Avogadro’s Number is the number of particles in a mole, N is the number of particles present with Activity A)
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\]

\[
\text{dose} = (0.5) \frac{0.0693(10^{-3} \text{ g})(6.022 \times 10^{23} \text{ / mol})6.02 \times 10^6 \text{ eV / decay}}{2.41 \times 10^4 \text{ yr}(2.39.0522 \text{ g / mol})(1 \text{ kg})} (1.6 \times 10^{-19} \text{ J / eV})
\]

\[
\text{dose} = 34.9 \text{ J / kg} \cdot \text{ yr}
\]
Plutonium-239 decays by alpha emission with energy 6.02 MeV. If you inhale 1 milligram of plutonium and it effects 1.00 kg of your lung, what would be your dose in rem if 50% of the energy is absorbed? What biological effect would that have on your body? Assume the lowest RBE for alpha particles.

\[
\text{dose} = 34.9 \text{J/kg \cdot yr}
\]

\[
\text{dose(rad)} = 34.9 \text{J/kg \cdot yr} \left(\frac{1 \text{rad}}{0.01 \text{J/kg}}\right) = 3490 \text{rad/year}
\]

**Roentgen Equivalent Man:** \(\text{rem} = \text{rad} \times \text{RBE}\)

\[
\text{dose} = 3490 \text{rad/yr}(10) = 34900 \text{rem/year}
\]

\[
= 34900 \text{rem/year}(1 \text{year/365 days})
\]

\[
\text{dose} = 95.6 \text{rem/day}
\]
Immediate Health Effects?  
Long Term Effects?  

\[
dose = 95.6 \text{rem/day}
\]

**TABLE 30.3**  
**IMMEDIATE EFFECTS OF RADIATION (ADULTS, WHOLE BODY, SINGLE EXPOSURE)**

<table>
<thead>
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<th>Dose in rem$^\dagger$</th>
<th>Effect</th>
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</table>

$^\dagger$Divide by 100 to obtain dose in Sv.
Routes for radioactive exposure
Internal vs External
Testing for Ingested Contamination

The most common test for exposure to radioactive material is a bioassay, usually by urinalysis. As with most cases of internal contamination, the sooner the test is taken after ingesting or inhaling the contaminant, the more accurate the results will be. Most major medical centers are capable of performing this test.
U-235 Fission Fragments

Most Probable: Cesium 137 & Strontium 90

In a reactor chain reaction:

(1) $^{235}_{92}U + ^1_0n \rightarrow ^{236}_{92}U$

(2) $^{236}_{92}U \rightarrow ^{95}_{39}Y + ^{139}_{53}I + 2^1_0n + 3.2 \times 10^{-11} J$

Yttrium

Conversion to energy per kg fuel:

*1 UNIT = energy use of one U.S. citizen in 1 year.
Strontium-90

• Half Life of 28 years.
• Does not occur naturally. It is a by product of fission.
• Beta emitter. Decays to Yttrium-90, also a beta emitter.
• Behaves like Calcium and concentrates in bone where it damages stem cells of the bone marrow critical to reproduction of cells that mediate immune function. Causes leukemia and auto-immune illnesses.
• Interferes with neuron communication leading to brain damage of developing frontal cortex (dyslexia, autism)
• Y-90 concentrates in the glands which controls hormonal function – interferes with estrogen and testosterone which contributes to breast and prostate cancer, sexual organs.
Strontium-90

• Large amounts of Sr-90 were produced during atmospheric nuclear weapons tests in the 1950’s and 1960’s.
• Large amounts of Sr-90 was released by Chernobyl.

Worldwide:

• Trace levels of Sr-90 in food especially dairy products and leafy vegetables which are major sources of dietary calcium.

• Every person alive today has ingested some strontium-90
Cesium-137

- Half Life of 30 years
- Decay Mode: BETA (0.19 MeV)
- Decay to Barium-137 that radiates gamma (0.6MeV)
- Behaves like Potassium and is taken up by living organisms as part of fluid electrolytes.
- Both internal and external hazard from cancer
- Ingested, it is absorbed in the intestine, settles in muscles, excreted after a few months.
- Radioactive cesium is present in soil around the world largely as a result of fallout from past atmospheric nuclear weapons test.
Iodine-131

- Half Life of 8 days
- Decay Mode: BETA (0.364 MeV)
- Organ most effected: Thyroid
- Pathways: Inhalation, food chain (milk, vegetables)
- Most serious fallout product from nuclear testing. Average American alive at the time received a thyroid radiation exposure of 2 – 300 rads.
- Chernobyl released 83 million curies of I-131
- Iodine-131 is produced by the fission of uranium atoms during operation of nuclear reactors and by plutonium (or uranium) in the detonation of nuclear weapons.
Plutonium 239

- Half Life of 24,000 years.
- Does not occur naturally. It is a by product of fission.
- Alpha emitter (5.15 MeV)
- Acts like iron and can cross the placental barrier to reach fetus.
- Concentrates in testicles and ovaries.
- 1 pound, if uniformly distributed, could hypothetically induce lung cancer in every person on Earth.
- 5 metric tons of plutonium are dispersed around the Earth due to nuclear tests, bombs, satellite burn ups, fires, accidents, spill and leakages.
Uranium U-238

- Half Life of 4.5 billion years.
- Alpha emitter (5 MeV)
- Wherever you find U-238 you will find all the 14 radioactive daughters of U 238 which emit all types of radiation up to 100 MeV in energy.
- Concentrates in bone and kidneys.
- Chemically behaves like Calcium.
- A severe exposure (of the order of one milligram in the kidneys) causes lesions of the tubular cells and deterioration of the kidney function.
Depleted Uranium

- After isotope separation, the remaining $^{238}\text{U}$ is said to be “depleted” as it is missing $^{235}\text{U}$ – however, $^{238}\text{U}$ is radioactive
- Uranium is a very dense metal (1.7 x Pb), making it ideal for use in armor and shell casings
Modern Nuclear War?

DU Used in Recent Wars:

Balkans: 200 Tons
Afghanistan: 800 Tons
Gulf War 1: 350 Tons
Iraq War: 200 tons???
Genetic Effects and Birth Defects

Genetic effects and birth defects due to radiation exposure occur when radiation damage to a parent's DNA code is transmitted to a child. Genetic effects caused by radiation fall into two categories:

(1) effects that appear in the children of an exposed parent and
(2) effects that appear in later generations.

NEURAL TUBE DEFECTS
The neural tube develops into the spinal cord and brain. Defects occur when the neural tube fails to close completely during the early stages of pregnancy.
Why is Radiation More Damaging to Fetuses & Babies?

• Cells rapidly reproduce
• Damage to genes is not efficiently repaired
• If cell divides a defect is multiplied.
• Cellular damage can lead to greater risk of leukemia or cancer
• Increased risk of premature birth, low birth weight, birth defects.
In early developmental stages of both humans, fish and other wildlife when cells rapidly reproduce, damage to the genes is not efficiently repaired, so that if the cell survives and divides a defect is multiplied. Thus cellular damage can lead to a greater risk of leukemia or cancer in the new-born than in the mother, typically by anywhere from ten to a hundred times as great, depending on the stage of development. Moreover, many studies have shown that there is also an increased risk of premature birth, low birthweight and birth defects. The damage is known to involve the developing immune, hormonal and central nervous systems that often does not become apparent until many years later.

Especially serious is damage to different parts of the developing brain such as the prefrontal cortex, which can result in dyslexia, autism, inability to control anger, attention deficit, and reduced cognitive ability leading to academic failure, drop-out, selfish behavior, depression, suicide and murder. The reason is that neurons communicate by sending out calcium ions, so that Strontium 90 and 89 can be substituted for calcium, with devastating results due to the enormous energy with which electrons or beta rays are ejected from the nucleus in the course of the radioactive transformation from Strontium-90 to Yttrium-90, destroying neurons in the process.
Nervous System Disease

**High-dose exposure**: cancerous and benign brain tumors in people exposed, and small brain size and mental retardation in children of women who were exposed during pregnancy.

**low-dose exposure**: brain cancer, neurological diseases, psychological diseases, dyslexia, autism, attention deficit
Thyroid Tumors, Cancer & Disease

THYROID NODULES

Thyroid nodules are lumps in the thyroid gland which may be benign or cancerous. "Cold nodules" are non-functioning lumps in the thyroid gland. "Hot nodules" refer to overactive thyroid lumps.

HYPOTHYROIDISM

Hypothyroidism is a condition caused by too little thyroid hormone in the body. Symptoms include fatigue, weight gain, intolerance to cold, decreased appetite, constipation, hoarseness, menstrual irregularities, dry skin and hair changes.
Autoimmune Diseases

AUTOIMMUNE DISEASE or AUTOIMMUNE DISORDER
An autoimmune disease is a disease caused by the immune system attacking the cells of one's own body rather than attacking foreign cells, such as germs.

AUTOIMMUNE HYPOTHYROIDISM
Autoimmune hypothyroidism: An autoimmune disease that prevents the thyroid from producing enough thyroid hormone.

AUTOIMMUNE THYROIDITIS
Damage to the thyroid caused when the body's immune system attacks and destroys cells in the thyroid.
Nuclear Workers & Brain Cancer

Cumulative average whole-body doses ranged from 0.67 - 4.75 rem.

There is a higher than expected number of deaths from brain cancer among the nuclear industry workers studied. While chemical exposure may contribute to the risk of cancer, the only common factor among the workers was exposure to radiation.

Lymphedema is an accumulation of lymphatic fluid in the interstitial tissue that causes swelling, most often in the arm(s) and/or leg(s), and occasionally in other parts of the body. Acquired lymphedema, can develop as a result of surgery, radiation, infection or trauma.
John Smitherman
US Navy

"We watched the Baker shot from a ship about 19 miles away from the explosion, and mist from the mushroom fell on the deck of our ship and sand fell on our deck, little pieces of metal and rocks. We tried to wash off as much of it as we could. The mushroom cloud stayed in the air for almost two days - we could see that."

Smitherman later developed lymphedema, a blockage of the lymph system that causes legs and arms to swell; he had to have both legs amputated.

On September 11, 1983, he died of cancer of the colon, liver, stomach, lung and spleen. He had claimed compensation for radiation damages. The Veterans Administration turned his claim down seven times. It is still pending.
How do we know about the Health Effects of Nuclear Radiation?
Radioactive Man Told US!
Animal Testing

The black star in the middle of the picture shows the tracks made by alpha rays emitted from a particle of plutonium-239 in the lung tissue of an ape. The alpha rays do not travel very far, but once inside the body, they can penetrate more than 10,000 cells within their range. This set of alpha tracks (magnified 500 times) occurred over a 48-hour period.
Human Radiation Experiments
Hundreds of Secret Experiments of Radioactive Material on Humans by the DOE 1944-1960

Obtained by Citizens by the Freedom of Information Act
Human Radiation Experiments
Associated with the
U.S. Department of Energy
and Its Predecessors

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U.S. Department of Energy
Assistant Secretary for Environment, Safety, and Health
Washington, D.C. 20585
July 1995
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Challenges
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- Brookhaven National Laboratory
- Hanford Sites
- Idaho Sites
- Lawrence Berkeley Laboratory
- Lawrence Livermore National Laboratory
- Los Alamos National Laboratory
- Oak Ridge Sites
- University of California, Los Angeles
- University of Chicago Argonne Cancer Research Hospital
- University of Rochester
- Other

Radiation Terms
Listing of Experiment Titles

Foreword
Plutonium Injection

DURING 1945 TO 1947, 16 persons were injected with amounts of plutonium at the Manhattan Engineer District Hospital in Oak Ridge, Tennessee, (1 patient), at Strong Memorial Hospital in Rochester, New York (11 patients), at Billings Hospital of the University of Chicago (3 patients), and at the University Hospital of the University of California in San Francisco (3 patients). Excreta were obtained from patients and sent to Los Alamos for plutonium analysis. These data were used to establish mathematical equations describing plutonium excretion rates.

This research was funded by the Manhattan Engineer District; followup studies were supported by the U.S. Atomic Energy Commission and the U.S. Energy Research and Development Administration. (This experiment was referenced in the Malkey report and included in the DOE Roadmap of February 1995.)

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List of Experiments

Hanford Sites

HS-1. Ingestion of Iodine-131 in Milk by Hanford Employees

In 1963, milk from dairy cows fed iodine-131 (I^{131}) was consumed by eight General Electric/Hanford workers either as a single dose or as several daily doses. During the study, the amount of iodine in the cows' diet was increased from 5 milligrams per day to 2 grams per day. The resulting uptake by the human thyroid was determined in Hanford's whole-body counter facility. Participants were Hanford scientists who had volunteered to drink the milk and be counted over a period of approximately 1 month. This work was supported by the U.S. Atomic Energy Commission. (Previously described in #41 on the original list of 48 experiments released by DOE in June 1994 and included in The DOE Roadmap of February 1995)

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OT-60. Studies of the Metabolism of Maternally Inherited Iron in Newborn Infants Using Iron-55
OT-61. Thyroid Function Studies Using Iodine-131
OT-62. Interlaboratory Comparison of the Reliability of the Measurement of Cesium-137 in Human
OT-63. Metabolic and Gastrointestinal Absorption Studies with Short-Lived Decay Products of Radium and Thorium
OT-64. Comparison of Iodine-123 and Iodine-131 for Thyroid Uptake Studies
OT-65. Iodine-131 Localization
OT-66. Tolerance to Whole-Body Irradiation of Patients with Advanced Cancer
OT-67. Modification of the Distribution and Excretion of Lanthanum-140 by Chelating Agents
OT-68. Metabolism Studies Using Strontium-85 and Calcium-45
OT-69. Strontium Metabolism Studies Using Strontium-85
OT-70. Studies on EDTA and Strontium Excretion Using Strontium-85
OT-71. Comparative Metabolism Studies Using Strontium-85 and Calcium-45
OT-72. Effects of Increasing the Rate of Strontium-85 Excretion
OT-73. Decontamination of Skin Contaminated with Carbon-14, Fission Products, Tantallum-182, and Alpha Emitters
OT-74. Effects of Radium-224 Applied to Skin
OT-75. Effects of Strontium-38 and Thallium-38 on Skin
OT-76. Topical Absorption Studies Using Radium-224
OT-77. Effects of Polonium-210 on Skin
OT-78. Studies of the Transmission of Radiiodine to Infants Through Maternal Breast Milk
OT-79. Studies of Copper Metabolism Using Copper-64 in Healthy Subjects and Patients with Wilson’s Disease
OT-80. Studies on Copper Transfer Between Red Blood Cells and Plasma Using Copper-64
OT-82. Granulocyte Studies Using Phosphorus-32 in Utah Prisoners
OT-83. White Blood-Cell Production Studies Using Phosphorus-32
OT-84. Studies of Copper Metabolism Using Copper-64
OT-85. Biliter Studies Using Phosphorus-32 in Utah Prisoners
OT-86. Comparative Metabolism of Radium-226 and Strontium-85
OT-87. Total-Body Counter Calibration Using Cesium-137 and Potassium-42
OT-88. Study of Cortisone-Induced Granulocytosis Using Phosphorus-32-Labeled Isopolyfluorophosphate in Utah Prisoners
OT-89. Cesium-137 and Rubidium-87 Metabolism in Healthy Subjects and Subjects with Muscular Dystrophy
OT-90. Study of Granulocyte Kinetics During Endotoxin-Induced Granulocytosis Using Phosphorus-32 in Utah Prisoners
OT-91. Study of the Transfer of Iron-59 and Iodine-131 Between Mother and Fetus
OT-92. Metabolism Studies Using Strontium-85 and Calcium-45
OT-93. Measuring Extracellular Fluid Using Sodium-24
OT-94. Potassium Studies in Diseased Patients Using Potassium-42
OT-95. Potassium Studies in Women Using Potassium-42
OT-96. Sodium Volume Studies in Diseased Patients Using Sodium-24
OT-97. Studies of Potassium Metabolism in Hyperthyroidism Using Potassium-42
OT-98. Studies of Potassium Metabolism in Diabetes Using Potassium-42 Tracer
Experiments List

List of Experiments

Plutonium Injection

PI 1. Plutonium Injection Studies

DURING 1945 TO 1947, 16 persons were injected with amounts of plutonium at the Manhattan Engineer District Hospital in Oak Ridge, Tennessee, (1 patient), at Strong Memorial Hospital in Rochester, New York (11 patients), at Ellings Hospital of the University of Chicago (3 patients), and at the University Hospital of the University of California in San Francisco (3 patients). Excreta were obtained from patients and sent to Los Alamos for plutonium analysis. These data were used to establish mathematical equations describing plutonium excretion rates.

This research was funded by the Manhattan Engineer District; followup studies were supported by the U.S. Atomic Energy Commission and the U.S. Energy Research and Development Administration. (This experiment was referenced in the Malkey report and included in The DOE Roadmap of February 1995.)

References

Lawrence Radiation Laboratory, UCRL2850, 1971.

Durbin, P.W. Plutonium in Man: A New Look at the Old Data @ Section 7, Chapter 2 in Radiobiology of Plutonium, edited by E.J. Slower and
HS-5. Study of Metabolism of Strontium Using Strontium-85 as a Tracer

A STUDY WAS CONDUCTED in 1963 by scientists of the General Electric Hanford Laboratories to (1) determine whether ingested strontium is excreted in human body hair in measurable amounts, (2) determine whether analysis of hair samples was an accurate indicator of strontium uptake in man, and (3) investigate the biological retention of ingested strontium in man.

Two Hanford scientists voluntarily ingested a solution containing a few microcuries of strontium-85 (Sr$^{85}$). The exact amounts administered are not known. Hair clippings and facial shavings were then obtained from the subjects and analyzed for Sr$^{85}$ content.

The results of this study showed that Sr$^{85}$ could not be measured in small samples of body hair. This study was discontinued and the results were never published. The Hanford Laboratories were operated by the General Electric Hanford Company for the U.S. Atomic Energy Commission.
HS-2. Intentional Release of Iodine-131 at Hanford in 1963

IN JULY 1963, the Hanford Laboratory conducted a study that involved the release of 120 microcuries of iodine-131 ($^{131}I$) into the environment. These releases were designed to characterize the dispersion of radiation. The purpose of the experiment was to enable scientists to determine the fraction inhaled by men, the amount taken up by the thyroid, and the retention half-time of radioiodine in human thyroid.

Two volunteer subjects (Hanford employees), were stationed in the expected path of the radiation cloud. These subjects intentionally inhaled $^{131}I$ from the release and were subsequently measured for thyroidal uptake of $^{131}I$. These experiments were performed under contract with the U.S. Atomic Energy Commission. (Included in The DOE Roadmap of February 1995, and since revised)

References

Dr. Karl Z. Morgan, the Father of Health Physics @ Oak Ridge National Lab

“There is no safe level of radiation exposure.”