

Beta Radiation in the United States Following the Fukushima Disaster

by Bobby1

This is a statistical study of beta radiation in the United States following the Fukushima nuclear disaster. Its purpose is to assess the levels of beta radiation compared to an average background level, and its change over time. The data was obtained from the US Environmental Protection Agency (EPA) Radnet customized search.

Health risks from beta radiation are due primarily through internal exposure to beta particles. "Beta particles cause biological damage when they enter the body through inhalation, ingestion, absorption through the skin, or through a cut in the skin." (<http://www.psr.org/resources/health-risks-releases-radioactivity.pdf>)

Some of the radioactive isotopes which comprise beta particles, which may currently be found in the US, include:

| Isotope | Half-life |
|----------------|------------------|
| Iodine-131 | 8 days |
| Barium-140 | 12.7 days |
| Strontium-89 | 5.5 days |
| Strontium-90 | 29.1 years |
| Tellurium-129m | 33.6 days |
| Cesium-134 | 2.1 years |
| Cesium-137 | 30 years |

The data presented below involve concentrations of radioactive particles in air. The accumulation in soil and water is cumulative. Bioaccumulation in milk, meats, plants and human beings create increasing nonlinear effects. On the other hand, the relatively short half-lives of the isotopes involved (with the exception of Strontium-90 and the Cesium isotopes) lead to the decay, over time, in the intensity and health effects of these beta particles.

The levels of Gross Beta radiation (from air filters, expressed in pCi/m³) for the period March 15-May 23 were obtained for each of the years 2010 and 2011. The 2010 values for the corresponding month were considered to be background levels of beta radiation in the context of this study. The latest value for collection end date that was available at the time of this study was May 23, 2011. Tests of statistical significance were performed for the time periods March 15-31, April 1-30, and May 1-23. The null hypothesis (which was rejected in all cases) was that the values of gross beta radiation in 2011 did not increase over background. Each observation was weighted by the reciprocal of the number of observations for each city. The significance levels were obtained from optimal discriminant analysis.

| Time period | US beta radiation level | N | <i>p</i> < |
|--------------------|--------------------------------|----------|----------------------|
| March 15-31 | 5.09x background | 1093 | .001 |
| April 1-30 | 2.01x background | 1877 | .001 |
| May 1-23 | 1.15x background | 1173 | .011 |

Levels of beta radiation were also studied for selected individual locations in the US. This table represents the multiplier over background level for each city and month.

| City | March multiplier | April multiplier | May multiplier |
|----------------|-------------------------|-------------------------|-----------------------|
| Anchorage AK | 4.17x | 3.32x | 1.23x |
| Fairbanks AK | 2.06x | 3.37x | 1.14x |
| Birmingham AL | 1.69x | 1.20x | .86x |
| Little Rock AR | 1.95x | 1.16x | 1.02x |
| Phoenix AZ | 9.81x | 3.31x | .63x |
| Tucson AZ | 18.20x | 3.07x | 1.92x |
| Eureka CA | 53.05x | 19.82x | 6.46x |
| Los Angeles CA | 5.23x | 2.19x | 1.11x |
| Sacramento CA | 6.83x | 2.45x | 1.24x |

| | | | |
|-------------------|--------|-------|-------|
| San Diego CA | 11.42x | 2.59x | 1.53x |
| Riverside CA | 6.91x | 2.94x | 1.09x |
| San Francisco CA | 1.48x | 2.43x | .85x |
| Denver CO | 3.96x | 1.29x | 1.42x |
| Hartford CT | 2.07x | 2.96x | .82x |
| Jacksonville FL | 6.38x | .82x | .93x |
| Orlando FL | 8.13x | 1.07x | .77x |
| Honolulu HI | 23.98x | 1.38x | .94x |
| Hilo HI | 12.49x | 1.23x | 1.10x |
| Des Moines IA | 5.35x | 3.09x | 1.96x |
| Idaho Falls ID | 8.15x | 3.53x | .95x |
| Aurora IL | 2.27x | 3.06x | 1.10x |
| Indianapolis IN | 4.49x | 1.80x | 1.47x |
| Topeka KS | 2.09x | 1.27x | 1.33x |
| Lexington KY | 2.90x | .92x | .77x |
| Baton Rouge LA | 2.68x | .77x | .80x |
| Worcester MA | 1.77x | 2.12x | .79x |
| Baltimore MD | 2.06x | 1.85x | .76x |
| Portland ME | 1.23x | 1.76x | .39x |
| Detroit MI | 2.27x | 1.99x | 1.00x |
| Duluth MN | 1.07x | 1.78x | .86x |
| Jefferson City MO | 2.18x | 1.41x | 1.04x |
| Jackson MS | 3.16x | 1.07x | .92x |
| Billings MT | 1.82x | 1.04x | .58x |
| Charlotte NC | 1.82x | 1.10x | .81x |
| Bismarck ND | 1.53x | 1.33x | 1.23x |
| Omaha NE | 4.82x | 3.52x | 1.38x |
| Trenton NJ | 1.61x | 2.17x | .61x |
| Santa Fe NM | 1.12x | 2.37x | 1.39x |
| Las Vegas NV | 6.20x | 2.40x | 1.12x |
| Albany NY | 2.01x | 2.11x | .79x |
| Cincinnati OH | 2.35x | 1.89x | 1.42x |
| Cleveland OH | 1.91x | 1.62x | 1.28x |
| Portland OR | 2.16x | .64x | .32x |
| Pittsburgh PA | 1.59x | 2.01x | 1.21x |
| Columbia SC | 2.64x | 1.35x | 1.02x |

| | | | |
|-------------------|--------|-------|-------|
| Pierre SD | 2.13x | 1.70x | 1.42x |
| Dallas TX | 2.29x | 1.78x | .74x |
| Houston TX | 2.03x | 1.77x | .44x |
| San Angelo TX | 1.97x | 1.54x | 1.61x |
| Salt Lake City UT | 16.77x | 3.61x | 1.94x |
| Lynchburg VA | 4.33x | 1.56x | .82x |
| Virginia Beach VA | 2.90x | 1.34x | .66x |
| Olympia WA | 1.28x | 1.75x | .87x |
| Charleston WV | 1.88x | 1.10x | 1.39x |

It is also of interest to see the increase over the 2010 “background” level in absolute terms. The following table represents the absolute increase in 2011 gross beta (measured in pCi/m³) over background for each city.

| City | March increase | April increase | May increase |
|------------------|-----------------------|-----------------------|---------------------|
| Anchorage AK | .0135 | .0051 | .0005 |
| Fairbanks AK | .0105 | .0104 | .0006 |
| Birmingham AL | .0053 | .0030 | -.0017 |
| Little Rock AR | .0069 | .0017 | .0002 |
| Phoenix AZ | .1521 | .0337 | -.0055 |
| Tucson AZ | .1034 | .0136 | .0053 |
| Eureka CA | .0209 | .0056 | .0017 |
| Los Angeles CA | .0356 | .0067 | .0006 |
| Sacramento CA | .0327 | .0058 | .0010 |
| San Diego CA | .0779 | .0078 | .0026 |
| Riverside CA | .0490 | .0111 | .0006 |
| San Francisco CA | .0395 | .0042 | -.0004 |
| Denver CO | .0255 | .0021 | .0024 |
| Hartford CT | .0071 | .0110 | -.0009 |
| Jacksonville FL | .0327 | -.0016 | -.0005 |
| Orlando FL | .0455 | .0006 | -.0023 |
| Honolulu HI | .0559 | .0011 | -.0002 |
| Hilo HI | .0445 | .0009 | .0004 |
| Des Moines IA | .0298 | .0162 | .0044 |

| | | | |
|-------------------|-------|--------|--------|
| Idaho Falls ID | .0325 | .0144 | -.0003 |
| Aurora IL | .0131 | .0229 | .0009 |
| Indianapolis IN | .0255 | .0071 | .0026 |
| Topeka KS | .0123 | .0031 | .0022 |
| Lexington KY | .0111 | -.0007 | -.0016 |
| Baton Rouge LA | .0088 | -.0019 | -.0013 |
| Worcester MA | .0054 | .0083 | -.0014 |
| Baltimore MD | .0100 | .0067 | -.0019 |
| Portland ME | .0015 | .0047 | -.0041 |
| Detroit MI | .0097 | .0080 | .0000 |
| Duluth MN | .0006 | .0045 | -.0008 |
| Jefferson City MO | .0098 | .0045 | .0003 |
| Jackson MS | .0141 | .0007 | -.0007 |
| Billings MT | .0144 | .0004 | -.0045 |
| Charlotte NC | .0052 | .0009 | -.0016 |
| Bismarck ND | .0051 | .0023 | .0009 |
| Omaha NE | .0347 | .0271 | .0022 |
| Trenton NJ | .0065 | .0095 | -.0034 |
| Santa Fe NM | .0012 | .0112 | .0025 |
| Las Vegas NV | .0433 | .0094 | .0007 |
| Albany NY | .0094 | .0097 | -.0015 |
| Cincinnati OH | .0107 | .0079 | .0024 |
| Cleveland OH | .0069 | .0043 | .0012 |
| Portland OR | .0075 | -.0027 | -.0058 |
| Pittsburgh PA | .0056 | .0076 | .0012 |
| Columbia SC | .0143 | .0047 | .0003 |
| Pierre SD | .0093 | .0047 | .0018 |
| Dallas TX | .0112 | .0077 | -.0020 |
| Houston TX | .0080 | .0072 | -.0056 |
| San Angelo TX | .0078 | .0043 | .0047 |
| Salt Lake City UT | .1119 | .0230 | .0066 |
| Lynchburg VA | .0268 | .0063 | -.0017 |
| Virginia Beach VA | .0093 | .0024 | -.0034 |
| Olympia WA | .0228 | .0024 | -.0005 |
| Charleston WV | .0067 | .0009 | .0028 |

The top 15 increases in gross beta radiation for the selected cities are shown below. This will provide an index of the highest amounts of beta radiation caused by emissions from the Fukushima plant.

| City | March beta level increase |
|-------------------|---------------------------|
| Phoenix AZ | .1521 |
| Salt Lake City UT | .1119 |
| Tucson AZ | .1034 |
| San Diego CA | .0779 |
| Honolulu HI | .0559 |
| Riverside CA | .0490 |
| Orlando FL | .0455 |
| Hilo HI | .0445 |
| Las Vegas NV | .0433 |
| San Francisco CA | .0395 |
| Los Angeles CA | .0356 |
| Omaha NE | .0347 |
| Sacramento CA | .0327 |
| Jacksonville FL | .0327 |
| Idaho Falls ID | .0325 |

Arizona, Utah, and California had the highest amounts of airborne beta radiation. But Hawaii and, surprisingly, Florida also had high readings.

These figures will be assumed to be proportional to the *dry deposition* of radioactive particles. Additionally, rain and snow also contribute greatly to the amount of radiation deposited on soil. This is called *wet deposition*. The following table summarizes the total March rainfall for cities in Florida and west of the Rockies:

| City | March 15-31 Rainfall (inches) |
|-------------------|--------------------------------------|
| Phoenix AZ | 0.06 |
| Tucson AZ | 0.02 |
| Eureka CA | 8.02 |
| Los Angeles CA | 3.80 |
| Sacramento CA | 4.10 |
| San Diego CA | 1.32 |
| Riverside CA | 1.41 |
| San Francisco CA | 4.72 |
| Jacksonville FL | 1.84 |
| Orlando FL | 4.02 |
| Honolulu HI | 0.17 |
| Hilo HI | 6.53 |
| Idaho Falls ID | 0.74 |
| Las Vegas NV | 0.17 |
| Portland OR | 3.83 |
| Salt Lake City UT | 0.99 |
| Olympia WA | 3.58 |

Summarizing the March deposition of beta particles, we have the following states ranked in decreasing order of dry deposition:

1. Arizona
2. Utah
3. California
4. Hawaii
5. Florida

The following states are estimated to have the highest amount of March wet deposition:

1. California
2. Hawaii
3. Florida
4. Washington

5. Oregon

The areas with higher amounts of dry deposition of beta particles are likely to suffer relatively higher amounts of contamination in topsoil and vegetation. Radioactive particles would tend to collect on the surfaces of green leafy vegetables. Areas with high amounts of wet deposition would have higher amounts of beta particles deposited from rain, and especially snow. This would find its way into groundwater, and drinking water supplies for cities. The contamination levels are likely to be greater in areas with high elevations.

April saw a sharp dropoff in beta radiation in Florida and some other areas. The highest amounts were located in the following cities:

| City | April beta level increase |
|-------------------|----------------------------------|
| Phoenix AZ | .0337 |
| Omaha NE | .0271 |
| Salt Lake City UT | .0230 |
| Aurora IL | .0229 |
| Des Moines IA | .0162 |
| Idaho Falls ID | .0144 |
| Tucson AZ | .0136 |
| Santa Fe NM | .0112 |
| Riverside CA | .0111 |
| Hartford CT | .0110 |

May had a further dropoff, with many areas indistinguishable from background. Some areas, especially in the west and Midwest, were elevated, and the beta radiation increases over the whole US were still statistically significant.

| City | May beta level increase |
|-------------------|--------------------------------|
| Salt Lake City UT | .0066 |
| Tucson AZ | .0053 |
| San Angelo TX | .0047 |
| Des Moines IA | .0044 |
| Charleston WV | .0028 |
| Indianapolis IN | .0026 |
| San Diego CA | .0026 |
| Santa Fe NM | .0025 |
| Cincinnati OH | .0024 |

The reduction in levels of beta radiation should not be assumed to continue in the future, as long as the Fukushima nuclear power plant emits radioactive substances into the atmosphere. A large Iodine-131 release occurred on May 22-23 (which did not enter into this analysis), and the Wallow fire in Arizona has increased beta levels for many areas of the country.