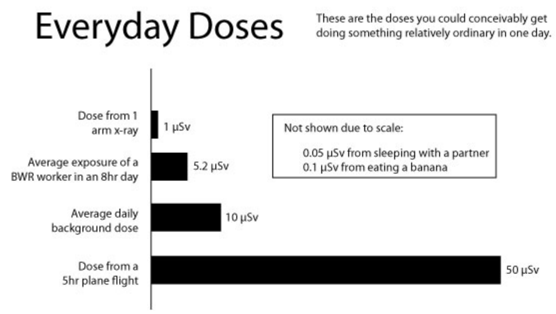
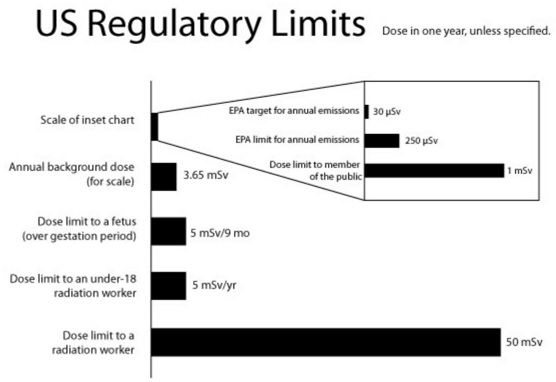
A Layman's Intro to Radiation

Updated 3/24 -- added discussion of inhaled/ingested radionuclides at bottom.

I've made this page in an attempt to explain some concepts in radiation to a general audience. I'm a Senior Reactor Operator at the Reed Research Reactor, and one of my many duties is being aware of radiation levels in the facility and adjusting my behavior appropriately.

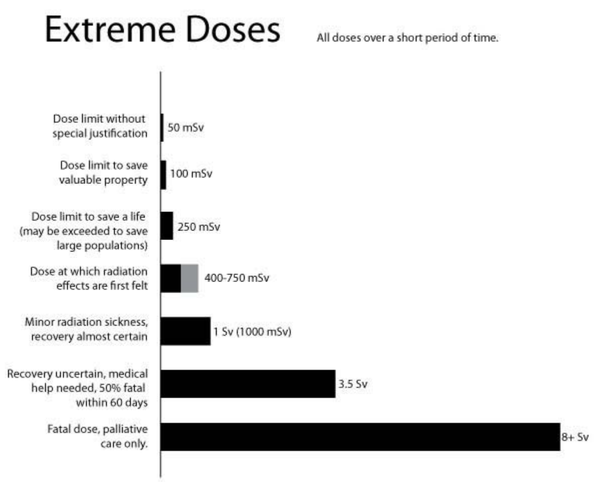
First, here's a chart laying out the scale of various doses. The top chart covers doses in one day, while the bottom covers doses over a whole year.





I separated these charts into doses received on a short timescale (in a day) and doses received on a longer timescale (a year) for a reason. A dose which is *acute*, that is, received over a short period of time, has a much greater biological effect than one received over a longer period of time. This is because radiation acts by depositing energy in tissue, damaging your cells. Very minor damage, repeated often, will be better repaired than a major assault. Doses can then cause either *deterministic* effects, where X dose causes Y problems, or *stochastic* effects, where X dose raises the probability of Y by Z amount. The most well-known deterministic effects are what's commonly known as radiation poisoning, while stochastic effects mostly consist of cancer of one sort or another. Both the timing and absolute dose determine the effect -- 1 Sv over the course of 20 years (a US radiation worker receiving his or her limit for the year 20 years in a row) will not cause radiation poisoning, but a dose of 1 Sv over 5 minutes certainly will.

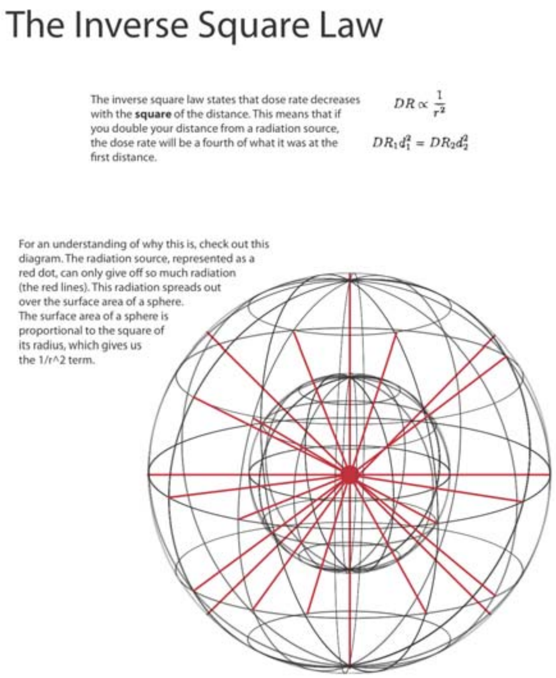
With that in mind, here is a chart outlining the more extreme doses -- where various effects set in, and what limits are in place in emergencies.



A brief digression on units: All units in these charts are in sieverts, the SI unit of effective dose. The SI unit of dose, the gray, is a unit of energy deposited in matter. 1 Gy is equal to 1 Joule/kilogram. Sieverts are calculated by multiplying grays by a quality factor based on the type of radiation producing the dose. The quality factor captures how bad the type of radiation is for you. For gamma rays, the most common and farthest-traveling form of radiation, the quality factor is 1. In the US, the government and many reactors use units of rem and rad, corresponding to sieverts and gray, respectively. 1 Gy = 100 Rad. Confusingly, Roentgens (pronounced renkens), an outdated unit of exposure, is sometimes used interchangeably with rem and rad.

Radiation Protection Measures

The easiest way to avoid getting a dose is to not be in the field in the first place. This is made easier by the *inverse square law*, explained in the graphic below.



What this means is, getting farther away from the radiation source goes a long way towards limiting your exposure.

If you can't get and stay far away from the radiation source, your second option to limit your dose is to just not spend that much *time* next to it. Radiation fields usually have units of dose rate, meaning the time you spend in them is just as important as the strength of the field.

Finally, if you have to spend a long time near a large radiation source, you can still limit your exposure by putting a lot of the appropriate shield between you and it. Lead is most commonly used, but if the source is giving off a lot of neutrons, you will want some water and boron instead. These three principles are often distilled down into just "time, distance, and shielding", and motivate many radiation protection measures.

Most of the rest are motivated by controlling radioactive contamination in the form of dust or aerosols, because ingesting, inhaling, or otherwise absorbing radioactive material into your body is worse than just standing in a field. This is what all this business with iodine pills is about -- iodine is retained in the thyroid, and iodine pills aim to flood the thyroid with regular stable iodine so the radioiodine can't hang out there. That said, don't all rush out to buy them -- they're pretty bad for you too, and shouldn't be taken unless you know you've actually been exposed to radioactive iodine. Entire west coast of the US: you haven't, stop panicking.

Inhalation and Ingestion

When radioactive material is inhaled or ingested, describing its effect gets a bit more complicated. One measure which seeks to provide an equivalence between inhalation/ingestion and external doses is the committed effective dose equivalent, or CEDE. Defined by the Nuclear Regulatory Commission, it describes the dose over the next 50 years to the affected organs, multiplied by a weighting factor based on how easily damaged the organ is. The 50 mSv dose limit on the chart above is the limit on both internal and external exposures. All internal exposures can be treated like this, providing an effective means of comparison between a hand x-ray and radioiodine thyroid treatments. If you're interested in the math, I've explained it here.

Hopefully, this information is helpful in providing some context about the still-unfolding events in Japan, as well as some general background on radiation protection. Comments, corrections, and complaints can be directed to emcmanis at reed.edu.

Sources:

- US Radiation Worker Dose Limits: http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/
- Yearly release targets and limits: http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/tritium-radiation-fs.html
- Many of the small dose numbers: http://www.deq.idaho.gov/inl_oversight/radiation/radiation_guide.cfm
- Dose from eating one banana: http://en.wikipedia.org/wiki/Banana_equivalent_dose
- Average dose to BWR employees: http://www.reirs.com/nureg2008/nureg2008.pdf
- Doses to save a life, etc: http://www.epa.gov/rpdweb00/docs/er/400-r-92-001.pdf
- Radiation sickness: http://en.wikipedia.org/wiki/Acute_radiation_syndrome ; http://www.umm.edu/ency/article/000026.htm ; Training manual.