Dear Neighbor,

This is your [Ourtown] plant radiation release package. It should contain

- a dosimeter,
- a [20] pack of N95 masks,
- a pamphlet with instructions for what to do if we do have a release, and an explanation of the release compensation program.
- a pamphlet explaining radiation for those who want to learn more about radiation damage and our bodies' ability to repair that damage.

If anything is missing or you have questions or you have children younger than ten in the house, please contact [1-nnn-nnn-nnnn]. We will be happy to send you child size masks. You can also arrange a tour of the plant at that number for your family.

Your neighbors that work at [Ourtown] plant are working hard to make a release very unlikely. But that does not mean it cannot happen. Based on past performance of the industry as a whole — which we are determined to better — there will be 1 release every 4000 reactor-years. Using this pessimistic number, there is a 1 in 100 chance, [Ourtown] will experience a release in the next 40 years. So while the likelihood of a release is small, we need to be prepared.

If we are prepared, we can handle a release. A release need not be harmful. Radiation is part of our natural environment. Our bodies know how to handle it. It takes a very large amount of radiation over a short period to cause a medical problem. No member of the public was detectably harmed by radiation in the releases at Three Mile Island and Fukushima. The only detectable radiation harm to the public after Chernobyl was to kids who drank contaminated milk. We will prevent that.

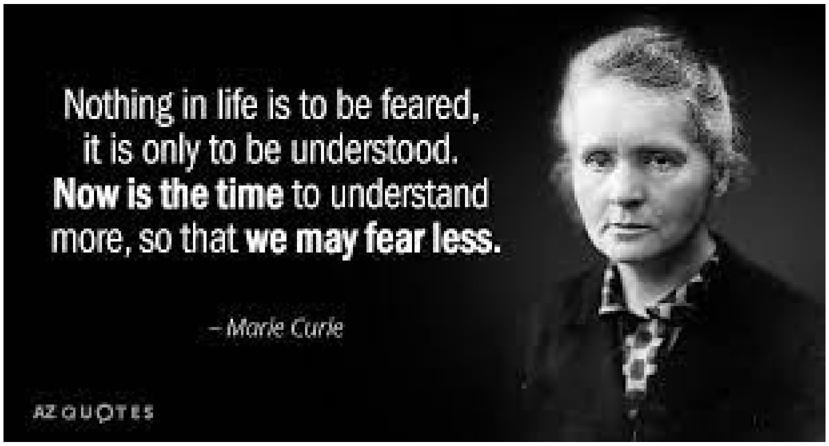
In all the releases to date, essentially all the harm to the public was caused by ill advised evacuations, and the unwarranted fear that drove those evacuations. If we properly prepare ourselves, we can avoid turning a managable disturbance into a community shattering disruption.

Please read the pamphlets. If you have any questions, you can call the above number, or go to our web site, [www.ourtown.net], and send us a message.

Sincerely,

Your neighbors at [Ourtown] power plant

What you should do if we have a release



During operation, Ourtown plant builds up an inventory of radioactive *isotopes*. Radioactive just means the isotope is unstable. It spontaneously decays to another isotope, releasing energy in the process. Normally, that energy in contained within multiple barriers within the plant and contributes to the electricity that the plant generates.

In a release some of these isotopes escape to the environment, where this energy can damage our DNA if it is absorbed into our bodies. The amount absorbed, the dose, is measured in units called millisieverts(mSv). A millisiert is a small amount (millijoule) of radioactive energy absorbed in a kilogram of tissue. Fortunately, our bodies are excellent at repairing radiation damage. However, our repair systems can be overwhelmed if they are hit with too much radiation too quickly. We have never reliably detected medical harm at dose rates below 20 millisieverts per day. Once the dose rates get much above 20 mSv per day, we start to see an increase in cancer; but then only if that daily dose is repeated over and over again for years.

Dose rates of 2 mSv per day or less offer at least a factor of ten safety margin. You need not be concerned about dose rates less than 2 mSv/day. If you would like to learn more about why this is the case, please see the pamphlet entitled Understanding Radiation which was included in your release package.

In a nuclear power plant release, almost all the damage is caused by iodine and cesium isotopes. Let's take iodine first.

Iodine and the Plume Each radioactive isotope decays at its own rate. which is measured by its *half-life*, the time it take for half of the isotope to decay to something else. If an isotope has a half-life of 1 year, half the isotope will disappear in the first year, another half in the second year, and so on. Ten half-lives will reduce the isotope to one-thousandth of its original mass.

The main iodine isotope, Iodine-131, has a half-life of about 8 days. As Figure 1 shows radioactive iodine will be essentially gone in about ten weeks. The problem is that about 20% of any iodine that is inhaled or ingested concentrates in the thyroid gland in our neck. The thyroid gland is tiny, less than one-thousandth of our total body weight.

Remember dose is radioactive energy per tissue weight. By concentrating in the thyroid, the iodine dose rate to the thyroid tissue can be magnified by a factor of a thousand relative to the ambient dose rate. An absorbed dose rate of 2 mSv/d is easily tolerable if spread over the entire body; but a thyroid dose rate of 50 mSv/d or more will cause cancer. We must avoid ingesting iodine contaminated food. This is particularly true for children.

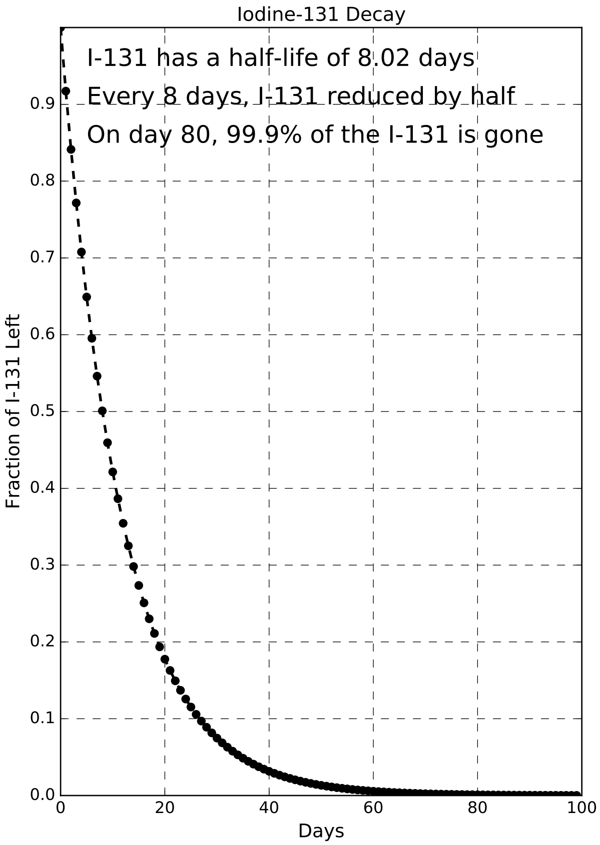


Figure 1: The decay of Iodine-131.

A cow grazing on contaminated grass will concentrate iodine in her milk. In the four big releases to date, even at Chernobyl, there has been no detectable radiation harm to the public with one very important exception. At Chernobyl, we had something like 4000 extra cases of childhood thyroid cancer. ***This was caused by the kids drinking iodine contaminated milk. This must be prevented.***

Fortunately, this is not difficult. It was done quite successfully at Fukushima. Any milk or milk powder produced prior to the release is fine. In a release, the Nuclear Monitoring Authority will monitor all milk and other produce produced in the region of the release. They will purchase and destroy any food that exceeds extremely conservative limits. Since iodine decays rapidly, all these restrictions can be relaxed within 100 days after the release has stopped.

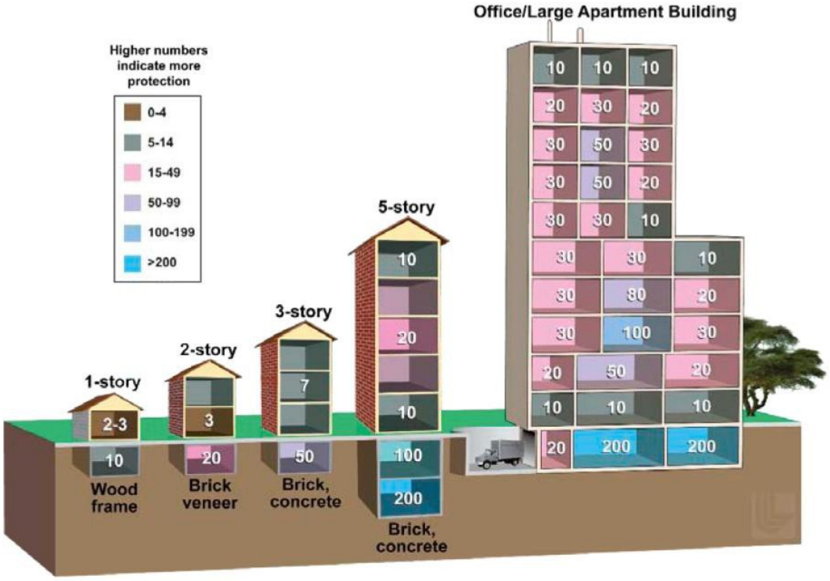


Figure 2: EPA estimate of dose reduction from staying in doors during plume. 10 means the indoor dose is one-tenth the outdoor dose.

The other pathway is breathing in iodine contaminated air. This is much less dangerous than ingestion. As a practical matter, this danger only applies during the plume passage. Here's what you need to do to handle the plume.

1. Go home. Make sure everybody is indoors. Keep the windows closed. Staying indoors during the plume passage can cut dose rates by a factor of two to ten or more, Figure 2. Halving the dose rate reduces the chance of cancer by more than a factor four. If you reduce your dose rate by a factor of ten, the chance of cancer is reduced by more than a factor of 100.
2. Monitor your phone, TV, and radio for the periodic reports which will be issued showing where the plume is and spelling out the current dose rates throughout the region.
3. Break out the dosimeter you were issued in the Release Package. Compare those reports with what the dosimeter is reading. Base your behavior on the larger of the public reports and your dosimeter measurements.
4. If the ambient dose rate outside your location is greater than 2 mSv/day, stay indoors as much as possible. If the dose rate indoors is greater than 2 mSv/day, have everybody mask up using the N95 masks that came in the Release Package. If you do go outdoors into an area where the ambient dose rate is greater than 2 mSv/d, mask up.
   Properly fitted, the N95 masks will reduce inhaled iodine by up to a factor of thousand, virtually eliminating any thyroid dose via this route.

After the release has been stopped and the plume has passed your location, the inhalation danger will drop off quickly. There will be little need for any further masking up.

By avoiding contaminated food and a combination of staying indoors and masking up during the plume passage, practically all the harm associated with radioactive iodine can be avoided.

Cesium and Groundshine After the release has stopped and the plume has passed, most of the dose will be from *groundshine*. This is direct, external radiation from material that has deposited on the ground. And almost all that radiation will be from Cesium.

Cesium comes in two isotopes: Cesium-134 and Cesium-137. The decay half-life of Cesium-134 is 2.1 years and 30.2 years for Cesium-137. Relative to iodine, cesium decay is a far slower process. However, the *effective half-life* of cesium will be reduced by a combination of:

1. Surface cesium being washed into sewers and bodies of waters by rain. Once the cesium is dissolved in water, the water provides effective shielding from groundshine. This process can be accelerated by washing down buildings and roads.
2. In open areas, the cesium will tend to percolate into the soil. Plants and soil bacteria will incorporate cesium. These processes tend to bury cesium, reducing the groundshine. This can be accelerated by plowing and washing down.

But effective dose rates are unpredictable and will vary widely from spot to spot. Surface material can get resuspended by strong dry winds, fires, and construction activity.

Your job will be to monitor the groundshine in your area by a combination of listening to the public reports, and taking readings with your dosimeter. If the ambient dose rate outdoors is less than 2 mSv/day, you and your family can go about life as normal. If the ambient dose rate outside is greater than 2 mSv/day, stay indoors as much as possible. At Fukushima, only portions of the two towns right next to the plant suffered maximal dose rates greater than 2 mSv/day for longer than two weeks.

Once the dose rates are below 2 mSv/day, they will continue to slowly decline. At this point, only a few precautions will be necessary. It is possible for fish and wild animals such as boar to concentrate cesium. The Nuclear Monitoring Agency (NMA) will continue to test and control commercial fish and other foods; but you should use judgement in consuming food that you caught or shot yourself. Mushrooms have a spectacular ability to concentrate cesium. Local wild mushrooms will be off limits indefinitely. Other than that you need only wait for your compensation check.

Your Release Compesation Package

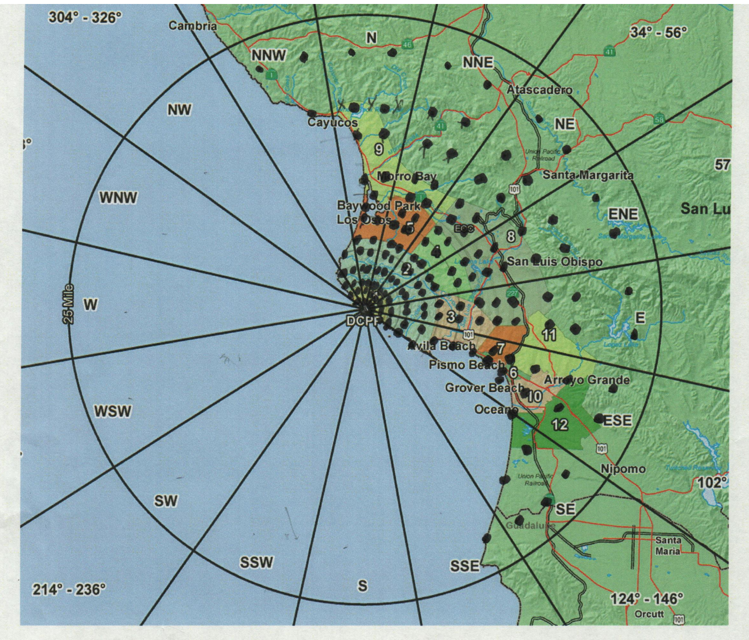


Figure 3: Schematic of Sensor Map. [Replace with actual map of Ourtown Sensors.]

Radiation Exposure Compensation Under the Atomic Energy Act of 2025, anyone who has been exposed to radiation from a nuclear power plant release is entitled to compensation. The program is entirely no-fault. You do not have to show negligence on the part of the plant. You do not have to show that you have actually been harmed. It is automatic and exclusive. Only government entities can take legal action against the plant for negligence or worse. Here's how it works.

Each US nuclear plant is required to maintain a network of radiation sensors throughout the area around the plant. In our case, this grid consists of [nnn] monitoring points located as shown in Figure 3. Check the map and locate the sensors closest to you. Each station is fitted with battery back up so that it functions even when the grid is down. These sensors are used during a release to let everybody know what the dose rates are throughout the area, whether they should stay inside and whether they need to mask up. The measurements are also saved for compensation purposes.

From these measurements, the Nuclear Monitoring Agency can make a pretty good estimate of the dose rate profile every resident of the area would have been exposed to ***had they spent all their time outside their home without masking up.*** Your actual absorbed dose rate will almost certainly be a small fraction of this *maximal* rate.

Each person's maximal dose rate profile is then input to a radiation harm model which estimates the risk of cancer from that dose rate profile. This model is very conservative. It assumes there is no dose rate below which the increased chance of cancer is zero, even though we cannot detect any increase in cancer at dose rates below about 20 millisieverts per day. On average contracting a fatal cancer shortens a life by about 12 years. Currently, government policy values a life year at $128,000. This number is adjusted annually for inflation. Combining the maximal increased chance of cancer with these numbers leads to a maximal number of lost life days and the corresponding radiation exposure compensation.

Every three months after a release, the NMA will compute your theoretical maximal exposure in the preceding quarter and the maximal lost life days associated with that exposure and send you a check for that amount. If the release was caused by an act of war or a terrorist attack, the compensation will be paid from the federal treasury. If not, it will be be paid by our plant's insurers. Once the quarterly compensation drops below $10 for a person, the exposure compensation will stop.

We do not know that exposure to low dose rate radiation leads to an increased chance of cancer. But we cannot say for sure that it does not. The radiation exposure compensation program adopts a precautionary philosophy combined with a set of extremely conservative estimates. By following the instructions in this package, you can just about guarantee that your family will be highly over-compensated for the radiation harm associated with a release.

Lost Earnings Compensation In addition to the radiation exposure compensation, you may be eligible for lost earnings compensation. If the maximal dose rate at your business or place of work is higher than 2 mSv/day, your employer has the option of closing up. If he does so, he will be compensated for the lost profits. But he can also elect to stay open, in which case he will still receive the compensation as if he had closed up. Thus, he has a strong incentive to remain open.

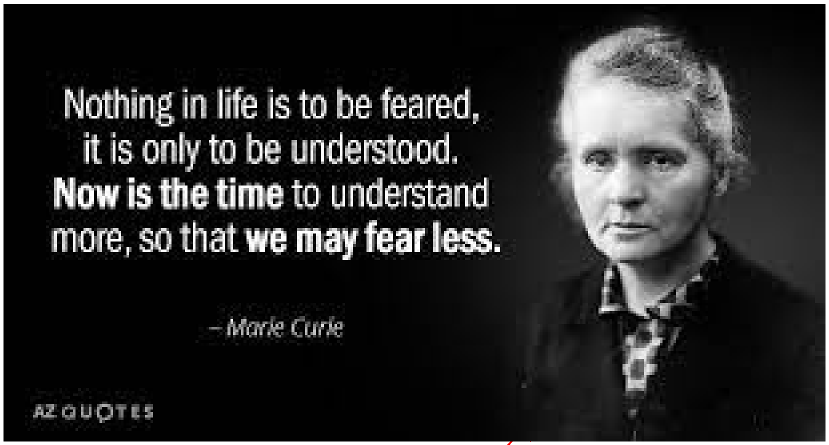
If the dose rate is over 2 mSv per day and your employer opts to shut down, you will be compensated for the lost earnings. If he elects to stay open, as long as the maximal dose rate at work or at your home is above 2 mSv per day, you have the right to not show up for work and be compensated for the lost wages. However, if you decide to go to work when the maximal dose rate there is above 2 mSv per day, you will still receive the compensation as if you did not go to work. In this case, you will be receiving double your normal income.

If the release was caused by an act of war or a terrorist attack, the lost earnings compensation will be paid from the federal treasury. If not, it will be be paid by the plant's insurers. As soon as the dose rate at your place of work drops below 2 mSv per day, the compensation will stop.

Evacuation You are of course free to evacuate at any time. If you do, you and your family will receive the same compensation as if you had not evacuated and not gone to work. However, there will be no additional compensation. The government recommends against evacuation unless the dose rate inside your home is well above 2 mSv/day and expected to stay there. Even dose rates in the 20 mSv/day range are very unlikely to produce a detectable increase in cancer.

Understanding Radiation will be a separate document in the release package.

Understanding Radiation


Nothing in life is to be feared, it is only to be understood. Now is the time to understand more, so that we may fear less.

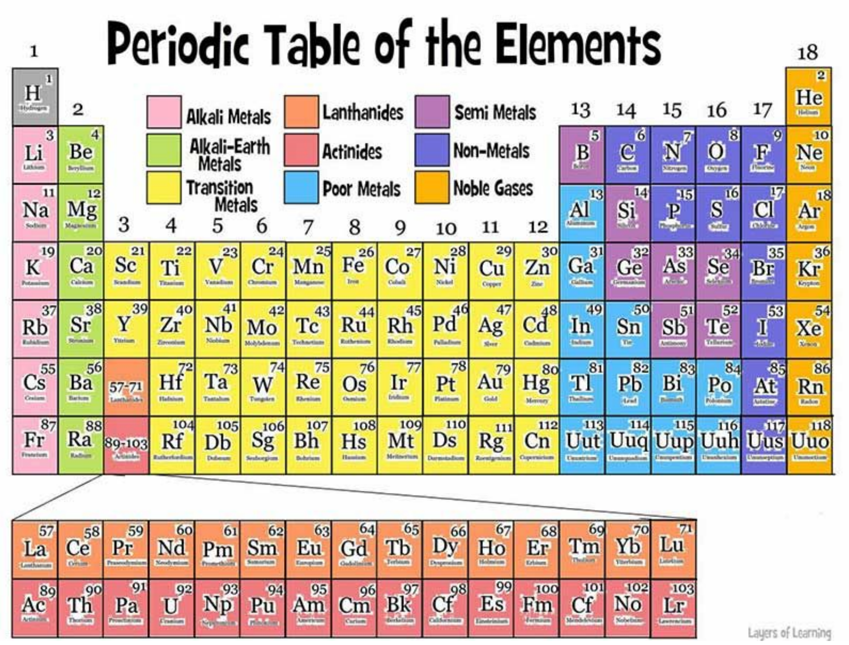
– Marie Curie

Radiation is natural. Radiation is everywhere. You are radioactive. Your dog is radioactive. We live in a sea of radiation. Without radiation we would not be here. Nuclear power uses radiation to create immense amounts of reliable, on-demand electricity with virtually no pollution or CO2 while consuming far less natural resources than any alternative.

But too much radiation too fast can be harmful. Like any other beneficial but potentially harmful substance, radiation needs to be understood. That understanding will allow us to employ radiation to the benefit of humanity, and respond intelligently to a release of radioactive material. Fortunately, radiation is pretty simple. Here's all we need to know.

Isotopes and Radioactive Decay Just about all ordinary matter is made up of about 100 *elements*, Figure 1. The elements in turn are made up of a tiny nucleus surrounded by a cloud of electrons. The nucleus is made up of protons and neutrons. Each element is distinguished by the number of protons in its nucleus; hydrogen has 1 proton, helium has 2 protons, and so on. But the number of neutrons in a hydrogen nucleus can be 0, 1, or 2. Most elements have the capability of accommodating differing numbers of neutrons in their nucleus, at least for a while.

A particular combination of protons and neutrons is called an *isotope*. Hydrogen nuclei with 0 or 1 or 2 neutrons are all isotopes of hydrogen, Figure 2. In this pamphlet, we will indicate an isotope by the element name followed by the total number of protons and neutrons, for example, Hydrogen-2. There are over 3000 known isotopes, but only a few are important in a nuclear power plant release.



Periodic Table of the Elements

🟥 Alkali Metals
🟩 Alkali-Earth Metals
🟨 Transition Metals
🟧 Lanthanides
🟥 Actinides
🟦 Poor Metals
🟪 Semi Metals
🟦 Non-Metals
🟧 Noble Gases

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57-71	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89-103	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo

57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Cf	102 No	103 Lr

Layers of Learning

Figure 1: The elements. [Highlight iodine and cesium.]

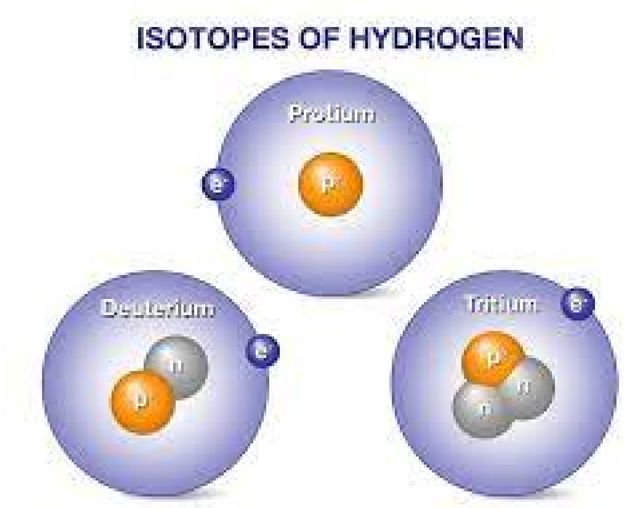


Figure 2: The three isotopes of hydrogen [Redo, dont need names]

A few isotopes will split into two much lighter isotopes when hit with a neutron. The only such isotope that occurs naturally in usable amounts is Uranium-235 (92 protons, 143 neutrons). When such an isotope splits or *fissions*, it releases a remarkable amount of energy, ***about 50 million times more energy than that created by combining a carbon atom with oxygen to produce CO2 during combustion.*** It also releases 2 or 3 neutrons. Under the right conditions, those neutrons can hit another fissionable nucleus producing a self-sustaining chain reaction. The job of a nuclear reactor is to maintain the right conditions for a chain reaction, while capturing the energy that is released in the process.

The lighter isotopes that result from this split are called *fission products*. Some of these fission products are unstable, combinations of protons and neutrons that cannot stay together for long. These unstable isotopes spontaneously *decay* to another isotope, a process that releases radiation. If the daughter isotope is also unstable, that isotope will decay to yet another isotope. This process continues until it reaches a stable daughter isotope.

Each unstable isotope decays at its own rate, which is measured by the isotope's *half-life*, the time it takes for half of the isotope to decay to something else. Some fission products decay extremely rapidly. They have half-lives that are a small fraction of a second. A few decay very slowly with half-lives of thousands of years. If an isotope has a half-life of 1 year, than half the isotope will have decayed in the first year after its creation, another half in the second year, and so on. Ten half-lives will reduce the isotope to one-thousandth of its original mass. The most harmful isotope early in a release is Iodine-131. It has a half-life of 8.02 days. Figure 3 shows how Iodine-131 decays. In four weeks, less than 10% of the iodine will be left. In eight weeks, less than 1% will still be around.

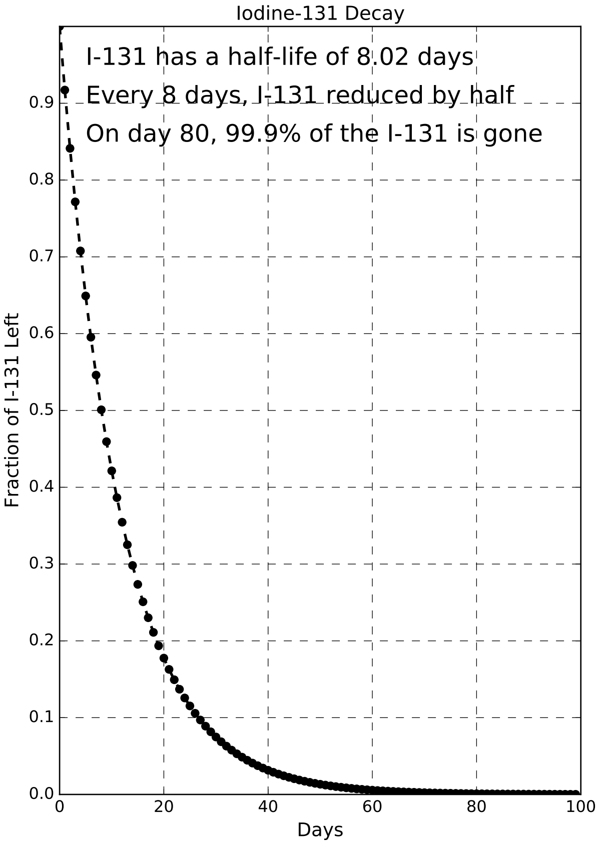


Figure 3: The decay of Iodine-131.

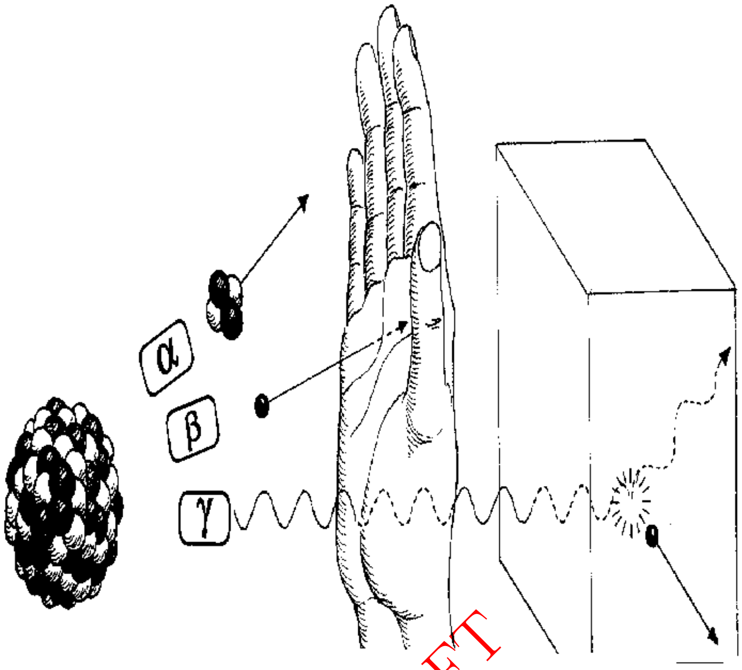


Figure 4: Penetrating and non-penetrating radiation. (Needs relabeling)

When an isotope decays, it releases energy. This energy can take one of three forms:

1. An alpha particle which is made up of two protons and two neutrons tightly bonded together. Alpha particles have no penetrating power. They are stopped by a few inches of air or a piece of paper.
2. An electron similar to the electrons produced by old fashioned, cathode ray televisions. Electrons have more penetrating power than alphas but not much. Few can penetrate very far into our skin.
3. A high energy photon. This is the same particle that makes up sunshine, but much higher energy. Photons have a great deal of penetrating power. A high energy photon can penetrate all the way through a human.

The practical implication is that isotopes that produce alpha particles and electrons must be ingested or inhaled to cause any damage. Only photons can hurt us from the outside.

Radiation Damage and Dose Rate Living tissue is made up of cells. Cells are mostly water. If one of the particles created by radioactive decay enters a cell, it transfers a portion of its energy to the cell mainly by breaking the chemical bonds that hold the water molecule together. This is called *ionization*. Particles with enough energy to do this are called *ionizing radiation*. Ionization creates chemically active oxygen molecules dubbed Reactive Oxygen Species (ROS), which can disrupt the cell's chemistry.

Radiation is all about the numbers. Since radiation is everywhere, it makes no sense to call something radioactive. The only question is how radioactive? We must get quantitative. The amount of energy that a particle deposits in tissue, the *dose*, is measured in joules per kilogram of tissue. This is then corrected for the particle's ability to inflict damage, resulting in a unit called a sievert (Sv). We assume radiation damage is proportional to the dose in sieverts; doubling the number of sieverts doubles the damage.

A sievert is a lot of radioactive energy, so in this pamphlet we will be dealing in millisieverts (mSv), one-thousandth of a sievert. The background dose rate in the USA ranges from around 0.005 to 0.02 mSv/d. But there are a few areas on the planet where the background dose rate is 0.2 mSv/d or higher. The background dose rate in [Ourtown] is [y.y] mSv/d.

In a nuclear power plant release, the primary concern is cancer due to damage to our DNA. The ROS created by radiation can alter our DNA, and a few of these mutations can survive and lead to cancer. Fortunately, Nature has endowed our bodies with a remarkably effective DNA damage repair system. This system can easily handle radiation dose rates of 2 mSv/d and more. But why are we equipped to repair damage from dose rates that are a hundred times larger than most of us will ever encounter?

DNA Damage Repair It turns out the DNA in our bodies is constantly being assaulted by Reactive Oxygen Species ***produced by our own bodies***! These bad-boys are the by-product of our oxygen based metabolism. About one-billion ROS micro-bombs per day per cell leak from our cell's energy factories, the mitochrondia, into the rest of the cell. Roughly 1 in 20 thousand of these molecules chemically damage our DNA. This is the price we pay for an oxygen based metabolism. This damage can take the form of Single Strand Breaks(SSB) and Double Strand Breaks(DSB). Scientists estimate that each of our cells faces about 50,000 Single Strand Breaks and 10 to 50 Double Strand Breaks each and every day.

In response to this onslaught, Nature has equipped us with a remarkably accurate DNA repair system. Without this system, we would not be here. SSB's are repaired

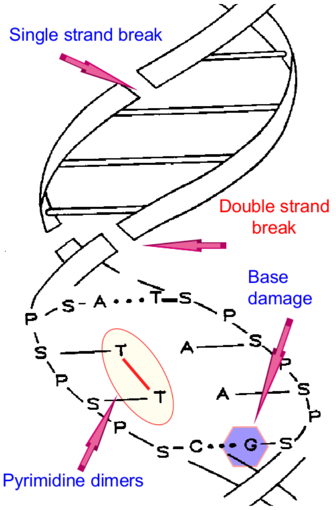


Figure 5: Single Strand and Double Strand DNA damage

almost automatically by the clever design of the double helix. The repair uses the intact strand as a template and is essentially error-less. SSB repair takes about 25 minutes.

DSB repair is far more difficult. In portions of the cell cycle, a backup template is available, and can be used to make a practically error-free repair. In the rest of the cell cycle, the attempts at repair, which take up to about 12 hours, cannot always be successful. The error rate is tiny; but it increases as the number of DSB's the cell faces rises. A portion of the incorrectly repaired DNA will survive and a portion of those mutations will escape our immune system and a portion of those will lead to cancer. Clearly, Double Strand Breaks are what we should worry about.

Scientists tell us we can expect 0.01 to 0.04 Double Strand Breaks per cell per millisievert. If we conservatively assume 10 DSB's per cell-day from our own body, and 0.04 DSB's per cell per millisievert, then it would take 250 mSv per day to equal the number of DSB's produced normally.

Unrepaired DNA damage can result in cancer. If normal non-radioactive damage is equivalent to a radiation dose rate of 250 mSv/d, and our bodies almost always repair that level of damage correctly, then cancer caused by any unrepaired damage associated with 2 mSv/d would almost certainly not be detectable. At the same time, it would not be surprising that we start to detect harm at 20 to 50 mSv/d. At that point, the cell is forced to deal with a substantially higher than normal number of DSB's. And in fact, we do start seeing an increase in cancer at about 20 mSv/d when that daily dose is repeated over and over for years, but nothing below that dose rate.

Bottomline, do not be concerned about dose rates in the range of 2 millisieverts per day.