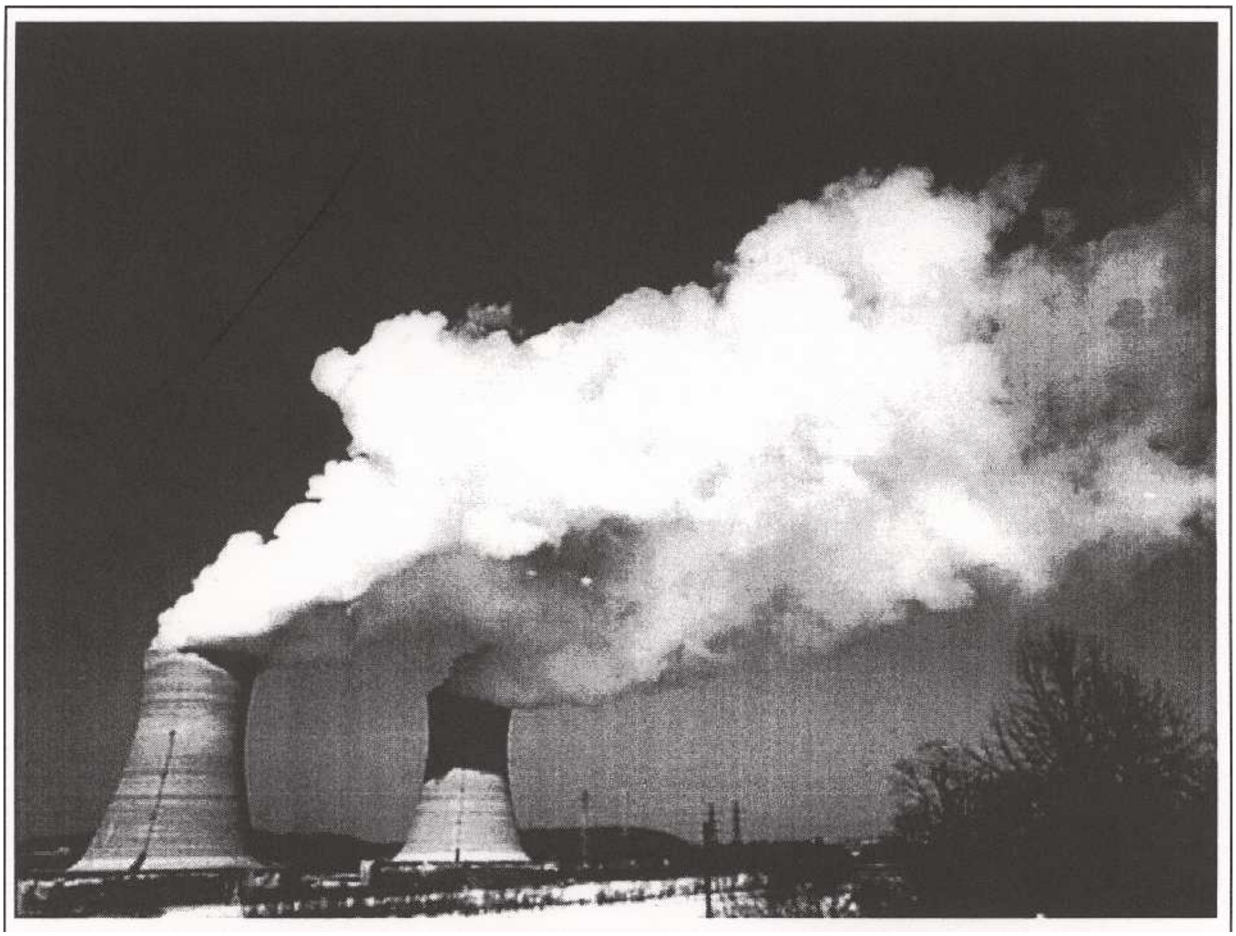
Nuclear Energy: the Good, the Bad, and the Debatable



Learn more about nuclear technology, its benfits, and its dangers.

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How is Nuclear Energy Produced?

Nuclear energy is produced when an atom's nucleus is split into smaller nuclei by the process called fission. The fission of large atoms, such as Uranium 235 and Plutonium 239, produces a great deal of energy. In fact, the fission of 1 gram of Uranium 235 produces the same amount of energy as the combustion, or burning, of 3 tons of coal (1)! The energy produced by the fission of uranium or plutonium can be harnessed to produce electricity, to propel space craft, and to power weapons like the Atomic Bomb.

Unlike a traditional coal-burning power plant, a nuclear power plant uses the energy, or heat, produced by the fission of Uranium, rather than the burning of coal, to heat water into the steam required to turn the turbines that power electric generators. The advantage of using Uranium over coal energy is that, unlike for coal, Uranium fission does not produce soot and potentially harmful gases such as Carbon Dioxide. However, like coal, Uranium is mined and then processed before it can be used as an energy source. Also, like coal, the different mining and processing steps, as well as the actual energy production, produce a great deal of waste. Unlike coal, however, these wastes are radioactive, and thus more difficult to handle.

What is radioactivity?

A radioactive element is an element that is unstable, and which continually decays by releasing radiation. Radiation is made up of high-energy particles or rays that can penetrate and damage the matter with which it comes into contact. The sun, for example, also releases radiation, which, in large doses, can damage our skin.

All elements that have an atomic number higher than 83, that is, all elements that have more than 83 protons in their nucleus, are radioactive. This includes Uranium, which has an atomic number of 92. It, like other radioactive elements, is located everywhere in nature and can be found in rock formations all over the world.

During the decay process, a radioactive element emits either an alpha or beta particle, which are sometimes accompanied by a gamma ray. In doing so, it changes from its original unstable form into other elements, called daughter elements, which can also be radioactive. These radioactive daughter elements also undergo decay, until, ultimately, a stable element is formed. This chain of decay is called a radioactive decay series. There are three series: the uranium series, the thorium series. and the actinium series. For example, the uranium series starts with Uranium 238, which changes into at least 14 different elements before it stabilizes as Lead 206. This series is outlined in Table 1 (2).

The length of time it takes for each element to decay depends on the type, as well as on the amount of the radioactive element present. The *half-life* of a radioactive material is the length of time it takes for half of that material to decay. Some radioactive elements, like Lead 214, have a half-life of seconds, some like Radon 222 have a half-life of days. and some like Uranium 238 have a half-life of 4.5 billion years. As you see, it can take a long time for radioactive materials to stabilize.

What are the different types of radiation?

There are three major types of radiation. That is, there are three forms of energy that are emitted by radioactive elements as they decay. First, there are alpha particles, which consist of 2 protons and 2 neutrons. These particles are highly energized, but because they are so large, can not penetrate matter very deeply, and can be stopped by a single sheet of paper. However, if these particles do manage to come into contact with unprotected, internal cells, by ingestion for example, they can be extremely harmful. Second, there are beta particles, which are the same as electrons. These are not as highly energized as alpha particles but can penetrate skin. Beta particles are also harmful when ingested, but since they are smaller they do not do as much internal damage. Third, there are Gamma rays. These electromagnetic waves, or photons, are similar to X-rays and can penetrate the body and organs easily. Gamma rays, though not as powerful as alpha particles, are dangerous because they are so invasive.

To understand the relative harm imparted by these three types of radiation, consider the following analogy. Let's say that alpha particles are the same as a really potent poison pill, beta particles are the same as an acid solution, and gamma rays are like a noxious gas. The poison pill isn't very harmful if you touch it, but can kill you if you swallow it. The acid solution would burn your skin if you touched it and is somewhat harmful if contacted in this manner. However, an acid solution would burn your insides if you drank it, and so is a lot more harmful if contacted in this way. In the case of the noxious gas, it permeates everywhere, since it is a gas, and even though it's not as deadly as the pill or the acid, you are more easily exposed to it. Of course, the amount of poison in the pill, of the acid in the solution, or of the gas in the air, and the length of time you are exposed to them affects how sick (or terminally ill) you become. This is also true for radiation.

The Nuclear Energy Debate:

The use of Nuclear Power has been controversial for a long time. Proponents of its use claim that it is a very 'clean' form of energy since very little fuel is needed to generate a lot of energy, and since no air pollution is produced, as in the burning of coal. However, because of accidents such as the one at Three Mile Island in the U.S., and the one at Chernobyl in the former Soviet Union, many people are opposed to Nuclear Power. Also, environmentalists, as well as other citizen groups, are concerned about the disposal of the radioactive waste generated by the mining, processing and use of Nuclear fuel. Currently. there are no universally acceptable methods for the storage and disposal of these wastes. and there is concern that buried wastes might leak into groundwater and eventually make it into surface waters or into drinking water supplies.

Are the concerns of these citizens well founded, or are they a result of misinformation? Is Nuclear Power less damaging to the environment than the combustion of coal and oil, which is connected to air pollution and global warming? Or, is radioactive waste a permanent problem? Even Scientists disagree on these issues. What do you think?

Table 1: The Uranium 238 Radioactive Series

Radioactive Elements	Half Life	Radiation Emitted
Uranium 238	4.5 billion years	α γ
Thorium 234	24.1 days	β γ
Protactinium 234	1.2 minutes	β γ
Uranium 234	247,000 years	α γ
Thorium 230	80,000 years	α γ
Radium 226	1,622 years	α γ
Radon 222	3.8 days	α
Polonium 218	3.0 minutes	α β
Lead 214	26.8 minutes	β γ
Bismuth 214	19.7 minutes	α β γ
Polonium 214	0.00016 seconds	α
Lead 210	22 years	β γ
Bismuth 210	5.0 days	α β
Polonium 210	138.3 days	α γ
Lead 206	STABLE	none

α = alpha radiation

β = beta radiation

γ = gamma radiation

References

(1) Petrucci, R. H., General Chemistry: Principles and Modern Applications. Macmillan Publishing Company, NY. 1985.

(2) The League of Women Voters, The Nuclear Waste Primer: A Handbook for Citizens. Nick Lyons Books: 1993.

Assignment # 1

The Web Search

Assignment 1: The Web Search

To learn more about Nuclear energy, conduct a search on the web. Use the list of web sites included in this packet as a starting point, and try to answer these questions as you go. Write down any questions you might have as you surf the net.

Facts:

1. How is nuclear energy produced?
2. Name 3 different uses for nuclear technology.
3. Name 3 States that have nuclear power plants.
4. Name 2 countries outside of the U.S. that use nuclear energy.
5. What is the fuel used at Nuclear Power Plants?
6. What are the different steps needed to produce the fuel used in Nuclear Power Plants?
7. What pollutants are produced in each of these different steps?
8. What are the steps from fuel to power at a Nuclear Power Plant?
9. How and where is nuclear waste stored and disposed of in this country?

Viewpoints:

1. Find a web site that promotes the use of Nuclear energy. What uses are cited? What arguments do the authors use to support their position?
2. Find a web site that is against the use of Nuclear energy. What hazards are cited? What arguments do the authors use to support their positions?
3. Is there conflicting information on the two web sites?
4. Do these two sites include the same scientific data at all?
5. Are you in favor or against the use of Nuclear energy? Are you in favor of only some uses? Cite the reasons for your opinions.
6. How much has this web search influenced your opinion?

Assignment # 2

Radiation Exposure and Dose

See Selected Solutions at the end of the packet.

Assignment 2 - From dose to death.

How much time can you sit out in the sun before you get burned? Would the solar radiation from one sunburn give you skin cancer? If not, how many sunburns would it take? Would long-term sun exposure (even without sunburns) be enough to give you cancer? How would you go about figuring out the relative impact of one long day at the beach without sunscreen, vs. a summer of doing yard work with sunscreen? Besides, not all sun exposure is bad. We need the sun's rays to help us break down Vitamin D, which is essential to healthy skin. Where is the trade off?

When it comes to nuclear radiation, there is also a health trade off. For example, nuclear radiation can be used to kill cancer cells in humans. It can also be used to image the body, like in MRIs and X-rays, in order to diagnose disease and injury. These are both positive things. However, uncontrolled radiation exposure from sources such as radon in our basements, or from nuclear power plant accidents, or from poor nuclear waste disposal can do us a lot of harm.

So, how much radiation would it take to give someone cancer? How much to kill them? Scientists are still trying to link radiation exposure to disease, but it's not easy to quantify a radiation dose since it depends on several factors, such as the length of time that person is exposed, whether they ingested the radiation or walked by it, whether the source emitted alpha, beta, or gamma radiation, and which body organs were exposed.

For example, the radiation absorbed by the body is different for alpha, beta, and gamma radiation. Exposure to alpha radiation is considered to be 20 times more severe than exposure to beta or gamma radiation. That is, if you are exposed to 1 unit of alpha radiation by ingestion, for example, it's the same as being exposed to 20 units of beta or gamma radiation. And if you think that's confusing, consider this: the risks increase depending on which body part comes into contact with that radiation. Your lungs are more than 2 times more likely to be damaged by radiation than, let's say, your bladder. So, in some cases, if you breath radiation it's worse than if you drink it.

The unit used in quantifying radiation dose is called the Sievert (Sv). The Sievert is the ratio of the radiation energy (Joules) to the total mass exposed (kilograms). So, for example, it takes a lot more radiation energy to give a 300 pound football player a dose of 1 mSv (that's 0.001 Sv) than it does to give the same dose to a 5 foot tall gymnast. This works in the same way that it would take more sugar to sweeten a gallon of coffee than a cup of it. To put the Sievert in perspective, consider this: an instantaneous dose of 1 to 3 Sieverts could cause you severe nausea and infection. An instantaneous dose of 10 Sieverts would kill you!

The average American is exposed to 3.6 milli-Sieverts per year under normal circumstances. Up to 80% of this radiation comes from natural background sources like the sun, rocks, and from concrete and brick. Of course, this exposure varies with location. For example, people living in the mountains are exposed to more solar radiation than those at low elevations. Also, when you fly in an airplane, your exposure increases by almost 50%. This is because, at high elevations, there is less atmosphere to protect you against the suns rays.

So how do you link the many different exposures to disease in humans? And how do you regulate the emissions from nuclear power plants, or medical exposures?

As you can imagine, it's somewhat difficult for the government to regulate all the possible exposures from radiation. Currently standards do exist for Nuclear Power plant operation, for nuclear waste disposal, and for setting limits on medical exposures like in X-ray limits per year. Current federal regulations include limits on the amount of radiation that industrial workers are exposed to, as well as the amount of radiation that citizens living in the vicinity of a Nuclear Power plant are exposed to. You can look these up in the Code of Federal Regulations at your library or on the web at: http://www.WPI.EDU/Admin/Depts/Safety/RSO/IOCFR20/. The question is, are these regulations sufficient? Or are they too restrictive?

The assignment:

Using the tables included, answer the following to figure out how radiation can effect you:

1. How many X-rays can you receive in one day without feeling any health effects? How many X-rays, taken in one day, would it take to kill you? The Federal Regulations governing radiation dose limits stipulate that people living in the vicinity of a nuclear power plant can not be exposed to more than 1 mSv each year. How many X-rays per year is that equivalent to? Do you think the Federal Regulations are sufficient? People living in the vicinity of Three Mile Island during its accident were exposed to an additional 0.015 mSv that year. How many X-rays would give you an equivalent dose?
2. Is it more dangerous to live near a Nuclear Power plant, or be on an airline crew which flies 1200 miles per week? Can a flight from here to Tokyo cause nausea (for reasons other than motion sickness, of course)?
3. How many hours of television do you watch each week? Calculate your exposure to radiation from television viewing. Would you have been exposed to more or less radiation if you had lived near Three Mile Island during its accident?

Table 2: Symptoms associated with acute radiation exposure (dose for one day)

Dose (Sv)	Symptoms	Outcome
0-0.25	None	-
0.25 - 1	Some people feel nausea and loss of appetite	Bone marrow damage, lymph nodes and spleen damaged.
1 - 3	Mild to severe nausea, loss of appetite and infection	Same as above, but more severe. Recovery probable, but not assured,
3 - 6	Severe nausea, loss of appetite, plus hemorrhaging, infection, diarrhea, skin peels, and sterility	Death occurs if doses higher than 3.5 Sv are left untreated.
6 - 10	Above symptoms plus impairment of the central nervous system	Death expected
Above 10	Incapacitation	Death

Table 3: Typical dose for various exposures in the US

Dose	Activity
3.6 mSv/year	Background exposure from sun, rocks and building materials
2.4 mSv/year	Additional exposure to workers in the nuclear industry
0.01 mSv/year	Additional exposure to public from the nuclear industry
1.5 mSv/year	Additional exposure to airline crew flying 1200 miles a week
9 mSv/year	Additional exposure to airline crew flying to Tokyo (1 trip per week)
0.4 mSv	Exposure per dental X-ray
0.015 mSv/year	Additional exposure to public from accident at Three Mile Island
0.015 mSv/year	Exposure to TV viewers watching an average of 10 hours per week

Table 4: US Regulations on nuclear power plant for radiation exposure

Dose limit	Exposed Group
50 (mSv/year)	Industrial worker
l (mSv/year)	Public neighboring a Nuclear Power plant
0.02 (mSv/hour)	Public neighboring a Nuclear Power plant

Source: Turner, J. E.. Atoms. radiation. and Radiation Protection. John Wiley and Sons,. Inc.. 1995.

Assignment # 3

Researching Nuclear Energy

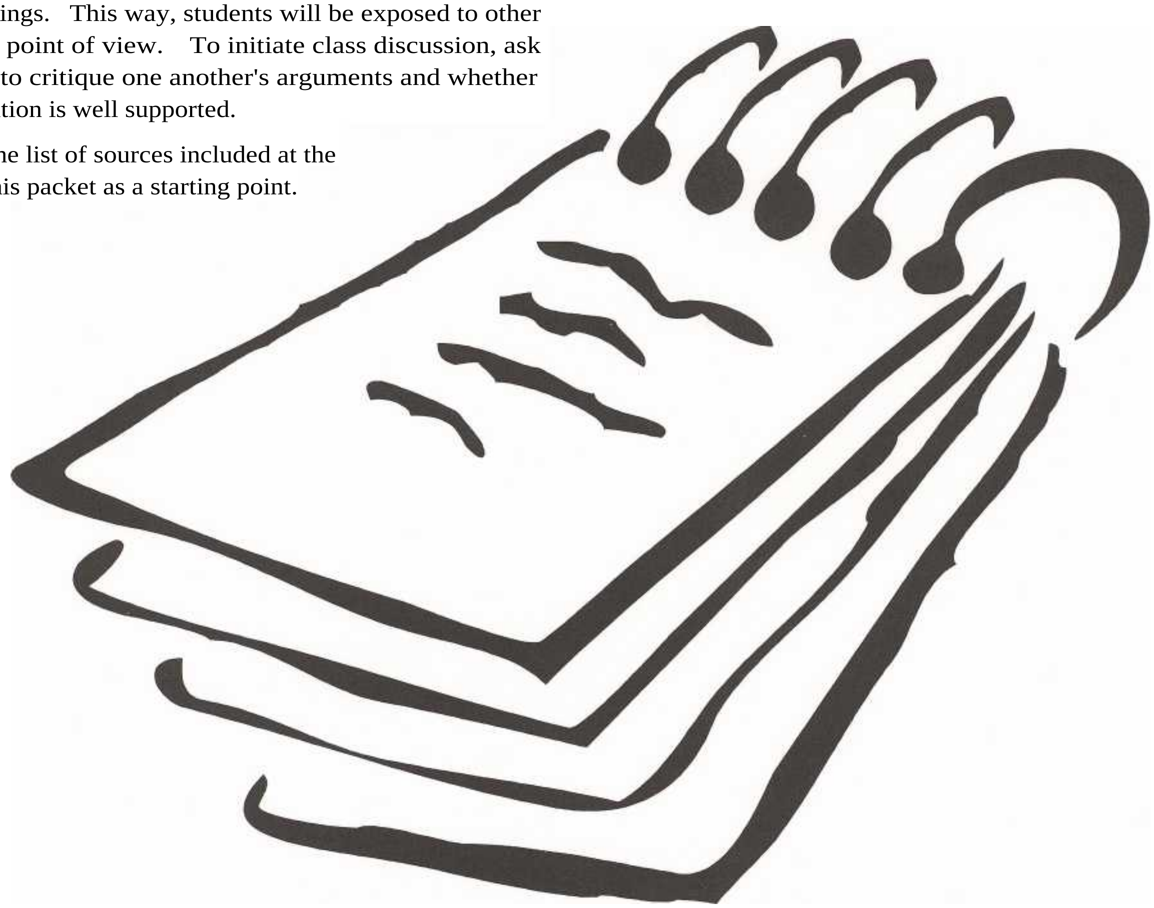
Suggestions to the teacher:

For this assignment, encourage students to include a case study from which to derive and to support their conclusions. For example, if a student wishes to compare the benefits and disadvantages of nuclear energy as a fuel, he or she could research France, which derives 80% of its energy from nuclear fuel. Also, the student can look at how France disposes of its wastes, if they've had safety problems or accidents, and to what degree the public supports is use. Encourage students to look at the questions from the civic, economic, historical, as well as the scientific, point of view.

At the end of their report, students include their opinions on whether nuclear energy should or shouldn't be used. Have them cite scientific, economic, environmental evidence to support their opinion.

Instead of, or in conjunction with, a written report, the students could give a 2 or 3 minute oral presentation of their findings. This way, students will be exposed to other students' point of view. To initiate class discussion, ask students to critique one another's arguments and whether their position is well supported.

Use the list of sources included at the endof this packet as a starting point.



Assignment 3: Researching Nuclear Energy.

Write a two page report on one or a combination of the following. Use and cite at least 3 sources of information. At least one source should be in printed form (i.e. books, journals, newspapers). This report should include one paragraph on whether you think Nuclear energy should or should not be used. Include economic, environmental, scientific facts or real life examples to support your opinion,

1. What is Nuclear energy?
   How is it produced. What are it's sources, What are its byproducts.
2. What are some uses of Nuclear energy?
   e.g. Fuel, medicine, weapons, space program
   Cite examples around the world.
3. What are the disadvantages of Nuclear energy?
   i.e. Waste disposal, human and environmental safety.
4. How does Nuclear energy compare to other sources of energy?
   Compare economic, environmental, social impacts.
5. What is this country's current waste disposal strategy?
   Who opposes it? Who supports it? How was it selected?

Assignment # 4

The Ad. Campaign

Assignment 4: The Ad. Campaign

Your state is planning to build a Nuclear Power Plant in your school district. In groups of 3 or 4, create an ad. campaign to either support or protest the plan. Use one or any combination of advertising media to get your point across. Distribute flyers, make posters, record radio spots, or film TV ads.

View and critique your classmates ads. Which ones do you think are effective? Why do you think those are effective? What facts are included, and what facts are excluded to support their position? Do they appeal to your common sense, or to your emotions? How? What would your reaction have been before you did research on Nuclear energy? Is it any different than your reaction now?

List of sources.

List of Books:

Brown, L., Renner, M., Flavin, C., Vital Signs 1997: The Environmental Trends that are Shaping our Future. Worldwatch Institute. W. W. Norton and Co., NY. 1997.

Flavin, C., Lenssen, N., Powering the Future: Blueprint for a Sustainable Electricity Industry. Worldwatch Paper 119. June, 1994.

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Petrucci, R. H., General Chemistry: Principles and Modern Applications. Macmillan Publishing Company, NY, 1985.

Slovic, P., Perception of Risk. Science, 236, 17 April, 1987.

Turner, J. E., Atoms, radiation, and Radiation Protection. John Wiley and Sons,, Inc., 1995.

List of Websites.

Nuclear Energy Sites

Department of Energy	http://www.doe.gov/
Los Alamos National Lab	http://www.lanl.gov/
Lawrence Livermore National Lab	http://www.llnl.gov/
Argonne National Lab	http://www.ani.gov/
Idaho National Environmental and Engineering Lab	http://www.inel.gov/
Savannah River Site	http://www.srs.gov/
Hanford Site	http://www.pnl.gov
Cogema (French Nuclear Company)	http://www.cogema.com/
British Nuclear Fuels	http://www.bnfl.com/
OECD Nuclear Energy Agency	http://www.nea.fr/
International Atomic Energy Agency	http://www.iaea.org/worldatom/
Amarillo National Resource Center	http://www.pu.org/

Nuclear Medicine: http://www.bih.harvard.edu/radiology/Modalities/Nucmed/nucmed.html

Opinion Sites

Atomic Energy Insights: http://ans.neep.vvisc.edu/-ans/point_source/AEI/AEI_home.html

Nuclear Links: http://wwvv.nuc.berkeley.edu/front_web_sites.html

Institute for Energy and Environmental Research: http://www.ieer.org/

Nuclear Waste Citizens Coalition: http://www.igc.org/citizenalert/nwcc/

Greenpeace: http://www.greenpeace.org/~nuclear/

Selected Solutions

Assignment 2 - From dose to death.

I. How many X-rays can you receive in one day without feeling any health effects? How many X-rays, taken in one day, would it take to kill you?

Minimum dose causing nausea: 0.25 Sv
Fatal dose given in one day: 10 Sv
Dose per X-ray: 0.4mSv
Nauseating # of X-rays: 0.25/0.0004 = 625
Deadly # of X-rays: 10/0.0004 = 25,000

The Federal Regulations governing radiation dose limits stipulate that people living in the vicinity of a nuclear power plant can not be exposed to more than 1 mSv each year. How many X-rays per year is that equivalent to?

Regulation limit: 1 mSv/year.
Dose per X-ray: 0.4 mSv.
Maximum # of X-rays: 1/0.4 = 2.5

People living in the vicinity of Three Mile Island during its accident were exposed to an additional 0.015 mSv that year. How many X-rays would give you an equivalent dose?

Exposure at TMI: 0.015 mSv
Dose per X-ray: 0.4mSv
Exposure from TMI accident is less than that of an x-ray.

2. Is it more dangerous to live near a Nuclear Power plant, or be on an airline crew which flies 1200 miles per week?

Regulation limit: 1 mS/year.
Exposure per year for crew flying 1200 miles per week: 1.5 mSv
Exposure due to flying is higher than exposure due to living near a nuclear power plant

Can a flight from here to Tokyo cause nausea (for reasons other than motion sickness, of course)?

Minimum dose causing nausea: 0.25 Sv
Exposure per year for crew flying 1 trip per week: 9 mSv
Exposure for 1 flight: 9/52 = 0.17 mSv
Exposure for 1 flight is less than nausea causing dose.

3. How many hours of television do you watch each week? Calculate your exposure to radiation from television viewing. Would you have been exposed to more or less radiation if you had lived near Three Mile Island during its accident?

Exposure at TMI: 0.015 mSv
Dose per year to viewers of 10 hours of TV: 0.015 mSv
Dose per hour: 0.015/(52*10) = 0.0288 µSv
Dose to student: Hours of TV per year * Dose per hour.
In essence, if the student watches more than 10 hours a week, they are exposed to more radiation than if they had been at TMI during the accident.