PLUTONIUM: ENERGY SOURCE OR DEATH SOURCE

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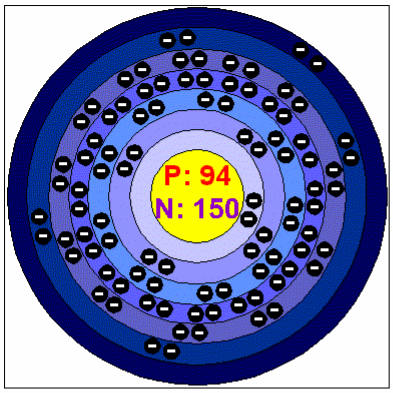
1. INTRODUCTION

A. What is Plutonium?

Plutonium (Pu) is a man-made element. The only evidence for naturally occurring plutonium is from a small source in South Africa where there once was a natural reactor. (Norbert Page, personal communication, August 1, 2006) Pu is created from Uranium (U). Uranium is the basic fuel of nuclear energy. Pu, a transuranic element, formed in a nuclear reactor through neutron capture, has several isotopes, some of which are fissile and some of which undergo spontaneous fission, releasing neutrons. About one third of the energy in a light water reactor comes from the fission of Pu-239. This is the main isotope of value recovered from reprocessing used fuel. As is the case with uranium, plutonium can also be recovered from spent fuel and recycled to create fresh reactor fuel. (WNA, 2005b) Pu is also the ingredient of a nuclear bomb. This cross of potential usages is the basis for the controversy over nuclear energy.

Chemical Elements.com - Plutonium (Pu)



Number of Energy Levels: 7

First Energy Level:2
Second Energy Level:8
Third Energy Level:18
Fourth Energy Level:32
Fifth Energy Level:24
Sixth Energy Level:8
Seventh Energy Level:2

Isotopes

Isotope	Half Life
Pu-236	2.87 years
Pu-237	45.2 days
Pu-238	87.7 years
Pu-239	24100.0 years
Pu-240	6560.0 years
Pu-241	14.4 years
Pu-242	375000.0 years
Pu-243	4.95 hours
Pu-244	8.0E7 years
Pu-245	10.5 hours
Pu-246	10.85 days

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B. Transuranium Elements

Plutonium is a transuranium element. This means that Pu was constructed in a laboratory facility. Transuranium elements are so called because they all lie beyond uranium; that is to say, they are elements with atomic numbers higher than 92 in the periodic table. All the transuranium elements are unstable, decaying radioactively, with half-lives that range from tens of millions of years to mere fractions of a second. Since only 2 of the 20 have been found in nature (neptunium and plutonium) and those only in trace amounts, the

synthesis of these elements through nuclear reactions has been an important source of knowledge about them. That knowledge has expanded scientific understanding of the fundamental structure of matter and makes it possible to predict the existence and basic properties of elements much heavier than element 112. Present theory suggests that the maximum atomic number could be found to lie somewhere between 170 and 210, if nuclear instability would not preclude the existence of such elements. All these still-unknown elements are included in the transuranium group. (Seaborg, 1997)

Table 28: Nuclear Properties of Selected Transuranium Element Isotopes

Nuclear Properties of Selected Transuranium Element Isotopes

name and mass	principal decay mode	half-life	specific activity	
			d/m/μg*	watts/gram†
Neptunium-237	alpha	2.14×10^6 years	1565	2.07×10^{-5}
Plutonium-238	alpha	87.74 years	3.8×10^7	0.570
Plutonium-239	alpha	2.411×10^4 years	1.38×10^5	$\sim 1.91 \times 10^{-3}$
Plutonium-242	alpha	3.733×10^5 years	8.73×10^3	1.13×10^{-4}
Plutonium-244	alpha	8.08×10^7 years	39.1	4.93×10^{-7}
Americium-241	alpha	432.2 years	7.6×10^6	0.114
Americium-243	alpha	7.37×10^3 years	4.4×10^5	6.45×10^{-3}
Curium-242	alpha	162.8 days	7.4×10^9	122
Curium-244	alpha	18.1 years	1.80×10^8	2.83
Curium-248	alpha	3.4×10^5 years	9.4×10^3	5.32×10^{-4}
Berkelium-249	beta (minus)	320 days	3.6×10^9	0.358
Californium-249	alpha	351 years	9.1×10^6	0.152
Californium-252	alpha	2.645 years	1.2×10^9	39
Einsteinium-253	alpha	20.47 days	5.6×10^{10}	1,000
Fermium-257	alpha	100.5 days	1.1×10^{10}	~200
Mendelevium-256	electron capture	78.1 minutes		
Mendelevium-258	alpha	51.5 days		
Nobelium-259	alpha	58 minutes		
Lawrencium-260	alpha	180 seconds		
Element 104-261	alpha	65 seconds		
Element 105-262	alpha	34 seconds		
Element 106-265	alpha	5-10 seconds		

* Disintegrations per minute per microgram. † Thermal power output.

C. Quantitative Risk Assessment

Quantitative risk assessments for high-level waste have been conducted by the scientific community. Pu has the ability to produce clean, cheep, safe electricity. (National Academy of Engineering, 2006) Nuclear energy is more efficient and produces fewer by-products than fossil fuel generated electricity. This alone makes nuclear energy a more environmentally friendly product. However, Pu has radioactive properties and the health effects of Pu exposure can be fatal.

II. WHAT ARE THE HEALTH RISKS FROM PLUTONIUM?

A. Plutonium Exposure and Cancer

Plutonium's most know heath risk is from inhalation. When inhaled, Pu can produce about 19 fatalities per pound or one eventual cancer for every 24 g of Pu. This number can be reduced to 3 per pound if the exposed persons breathe through a folded handkerchief to filter out the Pu particles. (Cohen, 1990) The risk is lessened because Pu dust particles tend to stick to each other and therefore are not easily dispersed. Additionally, the particles are readily collected on filters which are in use anywhere Pu powder is used. Professor Cohen (1990) explains, "…the air is exhausted through filters, which catch all but about one part per billion of the dust suspended in air." Dermal hazard of Pu is practically non-existing. (Norbert Page, personal communication, August 1, 2006) You can shower off the Pu dust and remain virtually unaffected. Ingested Pu is rarely discussed and highly improbable.

B. Potential for Developing Cancer

Comparison of Inhaled vs. Ingested Pu in Different Grades:

Entrance Mode	239-Pu	Reactor-Pu
Inhalation (dust in air)	1300	200
Ingestion with food or water	6.5 x 10^6	10^6
Cancer Doses in Micrograms		

The results are given are for the most important isotope of Pu, 239-Pu, which contains 1 curie of radioactivity for each 16g, and for the mixture of Pu isotopes that would be commonly found in power reactors, which is 6 times more intensely radioactive (1 curie in each 2.5 g). (Otto & Spinard, 1985)

C. Poison Inhalants

Comparison of Poison Inhalants Produced in the US:

Pu is not easily dispersed whereas the others are gases and hence readily dispersible. Of course, Pu released to the environment will last far longer than these gases, which would be decomposed chemically; nearly all of the damage done in Pu dispersal is by the initial cloud of dust. (Otto & Spinard, 1985)

Lethal Inhalation Doses Produced Annually in the U.S. (x 10^12)	
Chlorine	**400**
Phosgene	**18**
Ammonia	**6**
Hydrogen cyanide	**6**
Pu if all U.S. power were from fast breeder reactors	**1**

D. Grams of Pu Dispersed from Nuclear Reactors

Summary of Fatalities per Gram of Pu Dispersed from a Nuclear Reactor including Pu from Plant Uptake:

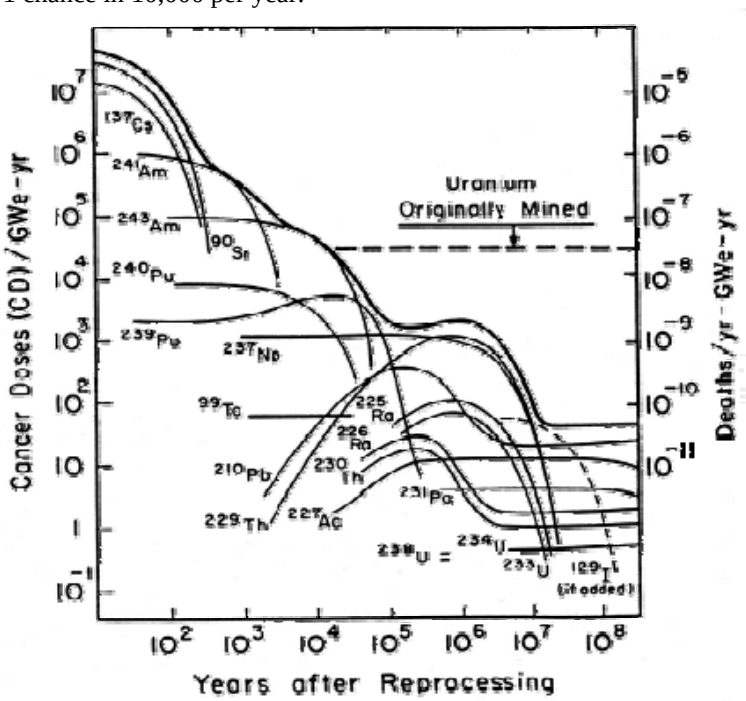
Appreciable amounts of Pu have gotten into the soil from bomb tests or from various research activities. Plant uptake is small for the same reason that Pu does not easily pass through the walls of the intestines -- it forms large molecules, which do not easily pass through membranes. Here we see that the total eventual effect of Pu dispersal in a city is one fatality per 18 g dispersed without warning, or 25 fatalities per pound. (Otto & Spinard, 1985)

Fatalities per Gram of Reactor-Pu Dispersed	
Inhalation from cloud	0.042 (1/24)
Resuspension	0.014
Long Term	0.0004 (1/2500)
Plant uptake into food	0.002
Total	0.058 (1/18)

E. Probability of Ingesting or Inhaling Plutonium

Professor Bernard Cohen (1984) of the University of Pittsburg addresses the hazards and possibilities of ingesting vs. inhaling Pu.

> We inhale about 20 cubic meters (m^3) of air per day, or 7,000 m^3 per year. Dust levels in air from materials on the ground becoming suspended are about 35 x 10^{-6} g/m^3. Thus we inhale (20 x 35 x 10^{-6} =) 0.7 x 10^{-3} grams per day of material from the ground, or 0.25 grams per year.
>
> The area of the United States is about 10^{13} m^2, so the volume of the top inch (0.025 m) of soil is (.025 x 10^{13} =) 2.5 x 10^{11} m^3. Since the density of soil is 2 x 10^6 g/m^3, this soil weighs (2 x 10^6 x 2.5 x 10^{11} =) 5 x 10^{17} grams. Since each person inhales 0.25 g/yr of this soil, the quantity inhaled by the U.S. population (240 x 10^6) is (240 x 10^6 x 0.25 =) 6 x 10^7 g/yr. The probability for any one atom in the top inch of U.S. soil to be inhaled by a human in one year is therefore (6 x 10^7/5 x 10^{17} =) 1.2 x 10^{-10}, a little more than 1 chance in 10 billion.
>
> The probability for an atom in a river to enter a human is very much larger. The total annual water flow in U.S. rivers is 1.5 x 10^{15} liters, whereas the total amount ingested by humans is (2.2 liters/person per day x 365 days/year x 240 x 10^6 = 1.8 x 10^{11} liters per year. Thus the probability for an atom in a river to be ingested by a human is (1.8 x 10^{11}/1.5 x 10^{15} =) 1.2 x 10^{-4}, or a little more than 1 chance in 10,000 per year.



Toxicity of high-level radioactive waste versus time. The ordinate is the number of cancer deaths that would be expected if all the waste produced by one large nuclear power plan in one year were eaten by people. The individual curves show the toxicity of the individual radioactive species in the waste (as labeled), and the top black curve shows their sum, the total toxicity. The horizontal dashed line shows the number of deaths expected if the uranium mined out of the ground to produce the fuel from which this waste was generated was fed to people. The

scale on the right shows the deaths per year expected according to the risk analysis. (Cohen, 1990)

III. ORIGINAL DISPOSAL PLANS

A. Conversion to Waste Glass

Disposal of the nuclear waste was originally (1977) to be converted into glass and placed into specially designed tubes that would then buried in Yucca Mountain. These calculations are derived from those plans.

B. Lethal Dose

Cohen estimates how much of the waste glass, converted into digestible form, would have a good chance of killing a person who eats it; "lethal dose." We calculate it by simply dividing the quantity of waste glass, l5 tons, by the values given by the curve in the above example and the results are as follows:

Shortly after burial	0.01 oz.
After 100 years	0.1 oz.
After 600 years	1 oz.
After 20,000 years	1 lb.

Nuclear waste looses toxicity with time due to radioactive material decay. When reviewing the toxicity of Pu and nuclear waste, we need to consider toxicity of common chemicals. Lethal doses for less feared substances occur in more minute quantities. Unlike, radioactive waste, these four chemicals retain their toxicity forever. (Cohen, 1977)

Arsenic trioxide	0.1 oz.
Copper	0.7 oz.
Selenium compounds	0.01 oz.
Potassium cyanide	0.02 oz.

C. Pu vs. Coal

Fatalities from Pu are not as common as most people fear. Air pollution from coal energy generation plants kill 10,000 people per year in comparison to one fatality every 300 years from Pu in the nuclear energy industry. (Cohen, 1990) This is not to say that Pu is not an environmental hazard. Only 10 kg of Pu is required to build a nuclear bomb that is powerful enough to destroy a city. (Sweet, 2006) However, when we are discussing nuclear energy, we must consider only the 0.6 g/year that may some day be released by the industry to the 5 million g. that has been dispersed into the atmosphere through nuclear bomb tests. Professor Cohen (1990) explains in his book entitled, *The Nuclear Energy Option*.

> …estimates on the same basis that we have been using (figures represented above) predict about 200 U.S. fatalities to date from Pu releases in bomb tests, and 4000 in the world. It also predicts about 200 fatalities worldwide from the reentry burn-up in 1964 of a space vehicle carrying a SNAP-9A 238-Pu-powered energy source. It is important to keep in mind that all of these estimates are theoretical. There is no direct evidence for Pu toxicity having caused serious injury to any human being, anywhere, ever.

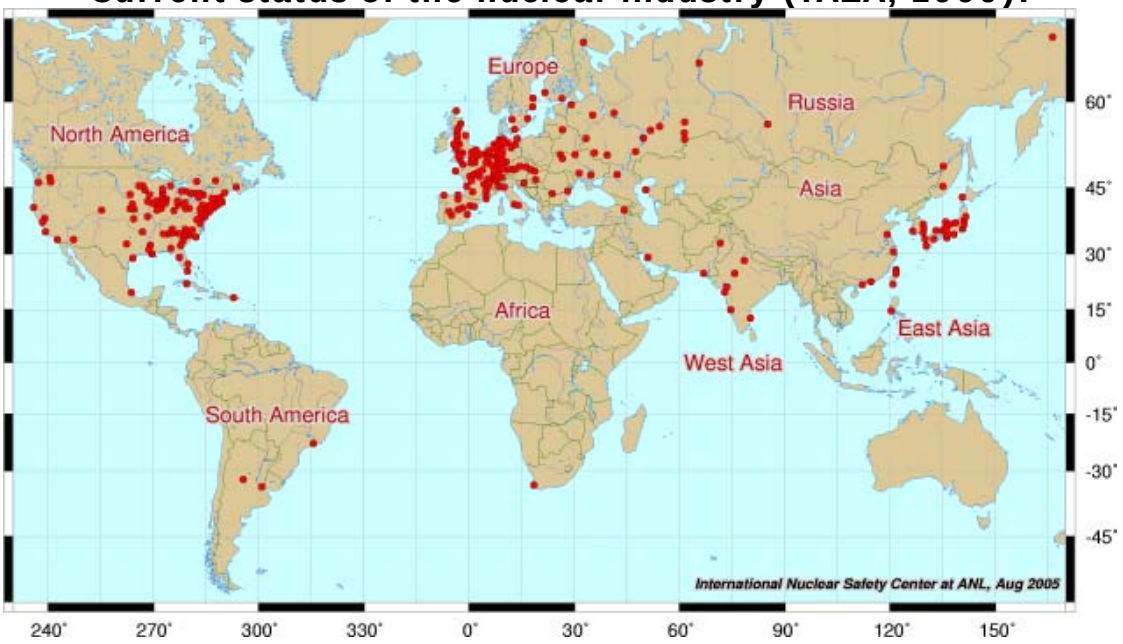
IV. CURRENT STATUS OF NUCLEAR INDUSTRY

A. Media Hype

Journalistic hype has contributed to the offensive stance against nuclear energy and Pu. The journalistic quote found in various references to Pu, "Most deadly substance on earth" is disproportionate to the true health effects. There are substances that can be considered more deadly due to their ability for wide spread damage and/or greater substantial local impact than Pu. "Because the public is afraid of plutonium, Ralph Nader, former Senator Ribicoff, John Gofman, and their like have done their work well, and the public is paying the price in its electric bills." (Cohen, 1990)

B. Nuclear Plant Locations

Current status of the nuclear industry (IAEA, 1999):



D. 442 nuclear power plants in operation with a total net installed capacity of 369.588 GW(e)
E. 6 nuclear power plants in long term shutdown
F. 27 nuclear power plants under construction

C. Nuclear Power vs. Coal Power

A brief view of nuclear power vs. fossil fuel proves that nuclear energy truly is safe, clean, efficient and affordable. "The USA now emits 11% more CO_2 than in 1990. At the Kyoto Climate Change Conference the USA promised to reduce CO_2 emissions to 8% below 1990 levels in 10 years, which is a decrease of 19% below present levels. If all the electricity now generated by nuclear power were to be generated by coal, CO_2 emissions would increase by another 8%, making it more difficult to meet this commitment if nuclear power was abandoned." (Wilson, 1999) The death toll attributed to coal generated energy is approximately 76:1 short term and 260:1 long term.

SUMMARY OF THE NUMBER OF DEATHS CAUSED BY THE WASTE GENERATED BY ONE LARGE POWER PLANT IN ONE YEAR, OR BY THE EQUIVALENT AMOUNT OF ELECTRICAL ENERGY PRODUCTION (Cohen, 1990)

MORE ON RADIOACTIVE WASTE

	Deaths Caused	
Source	**First 500 years**	**Eventually**
Nuclear		
High-level waste	0.0001	0.018
Radon emissions	0.00	-420
Routine emissions (Kr,Xe,T,^{14}C)	0.05	0.3
Low-level waste	0.0001	0.0004
Coal		
Air pollution	75	75
Radon emissions	0.11	30
Chemical carcinogens	0.5	70
Photovoltaics for solar energy		
Coal for materials	1.5	5
Cadmium sulfide	0.8	80

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D. Public Skepticism

It is the general publics' lack of knowledge about Pu and radiation that is the real culprit. Russ Paielli (2002) places the public's skepticism in perspective.

> The American public has been led to believe that nuclear power is extremely dangerous and that nuclear waste disposal is an unsolved problem. Those beliefs are based on preposterous distortions perpetrated by irrational environmentalists and an irresponsible mass media. In reality, a reactor meltdown would have to occur every *two weeks* to make nuclear power as deadly as the *routine emissions* from coal-fired power, from which we get about half of our electric power in the United States. (Note: some newer nuclear power plant designs cannot possibly meltdown.) And if the United States went completely nuclear for all its electric power for *10,000 years*, the amount of land needed for waste disposal would be about what is needed for the coal ash that is currently generated every *two weeks*.

People generally fear that which they do not understand. Few of us understand the nuclear industry and the elements that produce nuclear energy. The word radioactivity incites fear in even the most rational due to lack of understanding. Even Einstein did not know the extent that science would expand his $E=MC^2$ formula after British physicist

John Cockcroft teams with Ernest Walton of Ireland in 1931 to split the atom and go on to win the Nobel Prize in Physics for 1951.

E. History of Nuclear Technology

Nuclear technology is not new. It dates to the 1800s. The first U atom was split in 1929 by Physicists Otto Hahn and Fritz Strassmann of Germany, along with Lise Meitner of Austria and her nephew Otto Frisch, split uranium atoms in a process known as fission. They derived from this that the mass of some of the atoms converts into energy, thus proving Einstein's original theory. The U.S. Army's top secret Manhattan Project followed that same year. (National Academy of Engineering, 2006) In 1940, a transuranium element was first positively produced and identified, when two American physicists, Edwin Mattison McMillan and Philip Hauge Abelson, working at the University of California at Berkeley, exposed uranium oxide to neutrons from a cyclotron target. One of the resulting products was an element found to have an atomic number of 93. It was named neptunium. Pu followed shortly thereafter.(Seaborg, 1997) Powerful energy production was the final result of Einstein's theory. Harnessed, that energy can create power for life or power for death. Nuclear energy is not Hiroshima. It is electric generation for the new millennium.

V. UNDERSTANDING PLUTONIUM

A. Definition of Plutonium

In order to properly discuss Plutonium; we must understand the characteristics, measurements and properties of the man-made element. The encyclopedia Britannica defines Plutonium as:

> (Pu), radioactive chemical element of the actinide series in Group IIIb of the periodic table, atomic number 94. It is the most important transuranium element because of its use as fuel in certain types of nuclear reactors and as an ingredient in nuclear weapons. Plutonium, warm because of energy released in alpha decay, is a silvery metal that takes on a yellow tarnish in air. The element was first detected (1940) as the isotope plutonium-238 by Glenn T. Seaborg, Joseph W. Kennedy, and Arthur C. Wahl, who produced it by deuteron bombardment of uranium-238 in the 60-inch

cyclotron at Berkeley, Calif. Traces of plutonium have subsequently been found in uranium ores, where it is not primeval but naturally produced by neutron irradiation.

All plutonium isotopes are radioactive. The most important is plutonium-239 because it is fissionable, has a relatively long half-life (24,360 years), and can be readily produced in large quantities in breeder reactors by neutron irradiation of plentiful but nonfissile uranium-238. Critical mass (the amount that will spontaneously explode when brought together) must be considered when handling quantities in excess of 300 grams (2/3 lb). The critical mass of plutonium-239 is only about one-third that of uranium-235.

Plutonium and all elements of higher atomic number are radiological poisons because of their high rate of alpha emission and their specific absorption in bone marrow. The maximum amount of plutonium-239 that can be indefinitely maintained in an adult without significant injury is 0.008 microcuries (equal to 0.13 micrograms). Longer-lived isotopes plutonium-242 and plutonium-244 are valuable in chemical and metallurgical research. Plutonium-238 can be manufactured to harness its heat of radioactive decay to operate thermoelectric and thermionic devices that are small and lightweight but long-lived (the half-life of plutonium-238 is 86 years).

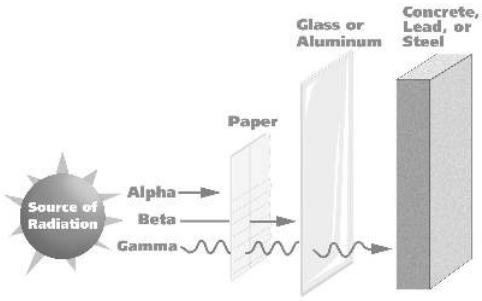
The EPA (2006) expands the explanation by adding that Plutonium has at least 15 different isotopes, all of which are radioactive. The most common ones are Pu-238, Pu-239, and Pu-240. Pu-238 has a half-life of 87.7 years. Pu-240 has a half-life 6,560 years. The isotope Pu-238 gives off useable heat, because of its radioactivity.

B. Radiation Poisoning

Understanding Plutonium and its properties is the first step to protecting yourself from radiation poisoning. Radiation "sickness" comes from radioactive waves in Pu and other radioactive substances. Radiation can be ionizing or non-ionizing. Ionizing radiation is the damaging type. It damages cells because it creates ions when it strikes something, which can then affect matter such as human tissue. The two main types of ionizing radiation are electromagnetic and particle. Ionizing electromagnetic radiation includes x-rays, gamma rays, and cosmic rays. Ionizing particle radiation involves alpha particles, which are helium nuclei, beta particles or electrons and neutrons. Gamma rays, alpha particles and beta particles are the main forms of radioactivity associated with nuclear power. (Taylor, 1996) Pu emits primarily alpha radiation and some low energy gammas/x-rays with disintegrations.

C. Radioactive Waves

Radioactive waves come in various forms. There are alpha, beta, gamma and x-rays.



"The alpha particle is the heaviest. It is produced when the heaviest elements decay. Alpha and beta rays are not waves. They are high-energy particles that are expelled from unstable nuclei. In the case of alpha radiation, the energy particles leave the nucleus. The alpha particle is a helium atom and contains two neutrons and two protons. It leaves the nucleus of an unstable atom at a speed of 16,000 kilometers per second, around a tenth the speed of light. Alpha rays are not very penetrating and are easily absorbed. The alpha particle emitter will not penetrate the outer layer of our skin but is dangerous if inhaled or swallowed. The delicate internal workings of the living cell forming the lining of the lungs or internal organs most certainly will be changed (mutated) or killed outright by the energetic alpha particle. The number of lung cancer cases among uranium miners from inhaled and ingested alpha sources is much higher than those of the public at large." (ABGX, n.d.)

D. EPA Protection Plans

Ingesting Pu is rare. The EPA has issued guidelines to quantify the allowable amounts of radioactive material in our water, soil, air and daily life through the Clean Air Act, Clean Water Act and other provisions. If ingested,

> …the stomach does not absorb plutonium very well and most plutonium swallowed with food or water passes from the body through the feces. When inhaled, plutonium can remain in the lungs depending upon its particle size and how well the particular chemical form dissolves. The chemical forms that dissolve less easily may lodge in the lungs or move out with phlegm, and either be swallowed or spit out. But, the lungs may absorb chemical forms that dissolve more easily and pass them into the bloodstream. (EPA, 2006)

Plutonium is easily absorbed by bone marrow. "Once in the bloodstream, plutonium moves throughout the body and into the bones, liver, or other body organs. Plutonium that reaches body organs generally stays in the body for decades and continues to expose the surrounding tissue to radiation."(EPA, 2006)

E. Radiation Exposure in Daily Life

Virtually everyone comes into contact with extremely small amounts of plutonium. The average person is exposed to radiation everyday. Radiation comes in natural forms, from

our television sets and microwave ovens, from medicine, from the energy industry, from atmospheric nuclear weapons testing and many other places in our daily lives.

> The average American's exposure to radiation (82%) comes primarily from natural sources. Fifty-five percent comes from radon, which is given off by radium, a component of soil and rock. Americans receive a smaller percentage of radiation from other terrestrial sources, such as uranium in the soil, and from cosmic rays. Eleven percent of natural radiation exposure is internal, primarily from radioactive potassium in our bodies. Eighteen percent of American's radiation exposure comes from man-made sources such as x-rays, nuclear medicine, and consumer products, much of which is the necessary byproduct of beneficial products and procedures. Americans receive only 0.1% of their total radiation exposure from nuclear energy production. This figure includes exposure from mining, milling, reactor operation, transportation, and waste storage. Interestingly, Americans receive 0.5% of their total radiation exposure from the radioisotopes released into the atmosphere from coal-fired power plants. We actually receive five times as much radiation from coal-fired power plants as we do from nuclear power plants. (Taylor, 1996)

F. Measuring Plutonium

Plutonium or radiation exposure is measured by an absorbed dose. An absorbed dose is the amount of energy absorbed per gram of tissue. This is what determines the risk posed to the human body. Not all exposure to radioactive items is fatal.

> Absorbed dose is expressed in *rad*. A *rad* is equal to 100 ergs of energy absorbed by 1 gram of tissue. The more modern, internationally adopted unit is the *gray* (named for the English medical physicist L. H. Gray); one gray equals 100 rad. It is important to realize that absorbed dose refers to energy *per gram of absorbing tissue*, not total energy. Someone absorbing 1 gray (100 rad) in a small amount of tissue, such as a thyroid gland, will absorb much less total energy than someone absorbing 1 gray (100 rad) throughout his or her entire body. Thus, when speaking of absorbed dose, it is crucial to know the amount of tissue being exposed, not simply the number of gray or rad. (DOE, n.d.)

Plutonium; radiation, is measured in rems and millirems. One mrem of exposure corresponds to being struck by approximately 7 billion particles of radiation, but it takes into account variations in health risks with particle type and size of person. Doses below about 10,000 mrem are commonly referred to as low-level radiation. (Cohen, 1990) The U.S. National Academy of Sciences Committee on Biological Effects of Ionizing Radiation (1990) and the United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR, 1988) has found that one mrem of radiation, received by the body, will increase that person's risk of dying from cancer by 1 in 4 million.

G. Health Effects from Radiation Exposure

This risk corresponds to a reduction in our life expectancy by 2 minutes. A similar reduction in our life expectancy is caused by: (Cohen, 1979)

- crossing streets 5 times (based on the average probability of being killed while crossing a street)
- taking a few puffs on a cigarette (each cigarette smoked reduces life expectancy by l0 minutes)
- an overweight person eating 20 extra calories (e.g., a quarter of a slice of bread and butter)

EPA - Health Effects (EPA's Radiation Protection Program: Understanding Radiation)

Exposure (rem)	Health Effect	Time to Onset
	radiation burns; more severe as exposure increases.	
5-10	changes in blood chemistry	
50	nausea	hours
55	fatigue	
70	vomiting	
75	hair loss	2-3 weeks
90	diarrhea	
100	hemorrhage	
400	death from fatal doses	within 2 months
1,000	destruction of intestinal lining	
	internal bleeding	
	death	1-2 weeks
2,000	damage to central nervous system	
	loss of consciousness	minutes
	death	hours to days

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Some scientists assert that low levels of radiation are beneficial to human health. This idea is know as hormesis, however, there do appear to be threshold exposures for the various non-stochastic effects. (Please note that the acute affects in the above table are cumulative. For example, a dose that produces damage to bone marrow will have produced changes in blood chemistry and be accompanied by nausea.) (EPA, 2006)

H. Protection from Exposure

Exposure to Pu can cause many health effects but protecting oneself from Pu damage is quite easy. As with all hazardous materials; respect the product and you can remain safe.

> External exposure to plutonium poses very little health risk, since plutonium isotopes emit alpha radiation, and almost no beta or gamma radiation. In contrast, internal exposure to plutonium is an extremely serious health hazard. It generally stays in the body for decades, exposing organs and tissues to radiation, and increasing the risk of cancer. Plutonium is also a toxic metal, and may cause damage to the kidneys. (EPA, 2006)

I. Plutonium as an Inhalation Hazard and Not a Proximity Risk

The real risk is inhalation not proximity as with most radioactive elements. Alpha waves can be blocked by paper. "One can actually handle plutonium and uranium metal without gloves although this is not recommended, mainly since there may be some metal particles that could be inhaled which then will do great harm." (Norbert Page, personal communication, August 8, 2006) Wearing long sleeves, gloves and pants (cover your skin) will protect you from proximity issues of Pu. Your best measure of protection is constantly using a proper filtration system when working with Pu. Working in a facility with a Pu filtration system and using a respirator protector gear for intense conditions is a simply way to minimize the risk of radiation poisoning from Pu. Dermal exposure to Pu dust can be washed off with a proper shower. Do not shake the dust off your clothing when removing to avoid creating a hazardous inhalation situation. Common sense dictates that you do not expose your food or eat in a room that may contain Pu dust particles to avoid ingestion of Pu. Should you become exposed, seek medical surveillance and treatment immediately. Degrees of exposure will vary accordingly to the length and purity of exposure to the various grades of Pu.

VI. BREEDING PLUTONIUM

A. Purity Factors

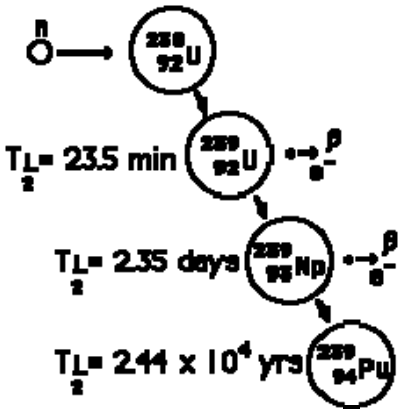
Plutonium varies in grades of purity. These grades of purity are referred to in layman's terms as "weapons grade" and "reactor grade" Pu. "Weapons grade" Pu is 93% pure whereas "reactor grade" Pu is only 63% pure. This purity or fissionability is where the difference lies. "Reactor grade" Pu or Pu-238 is not the ingredient of a nuclear bomb. It can be mixed with an explosive device to create a "dirty bomb" but it is not the coveted product of terrorists as many would have you believe. Pu-239, 240 and 241 are highly fissionable therefore appropriate for nuclear weaponry.

B. The Breeding Process

Sutcliffe and Trapp (1994) through the Lawrence Livermore National Laboratory explain the "breeding" process of Uranium into Plutonium.

> The most common isotope, plutonium-239, is produced when the most common isotope of uranium, uranium-238, absorbs a neutron and then quickly decays to plutonium. It is this plutonium isotope that is most useful in making nuclear weapons, and it is produced in varying quantities in virtually all operating nuclear reactors. As fuel in a reactor is exposed to longer and longer periods of neutron irradiation, higher isotopes of plutonium build up as some of the plutonium absorbs additional neutrons, creating plutonium-240, plutonium-241, and so on. Plutonium-238 also builds up from a chain of neutron absorptions and radioactive decays starting from uranium-235.

"Weapons grade" Pu is created in government facilities under strict controls. Pu-239, 240 and 241 are products that can be produced from Uranium (U-238) in breeder reactors. U-235 produces Pu-238 through neutron capture and beta decay. In short, fissionable plutonium-239 can be produced from non-fissionable uranium-238.

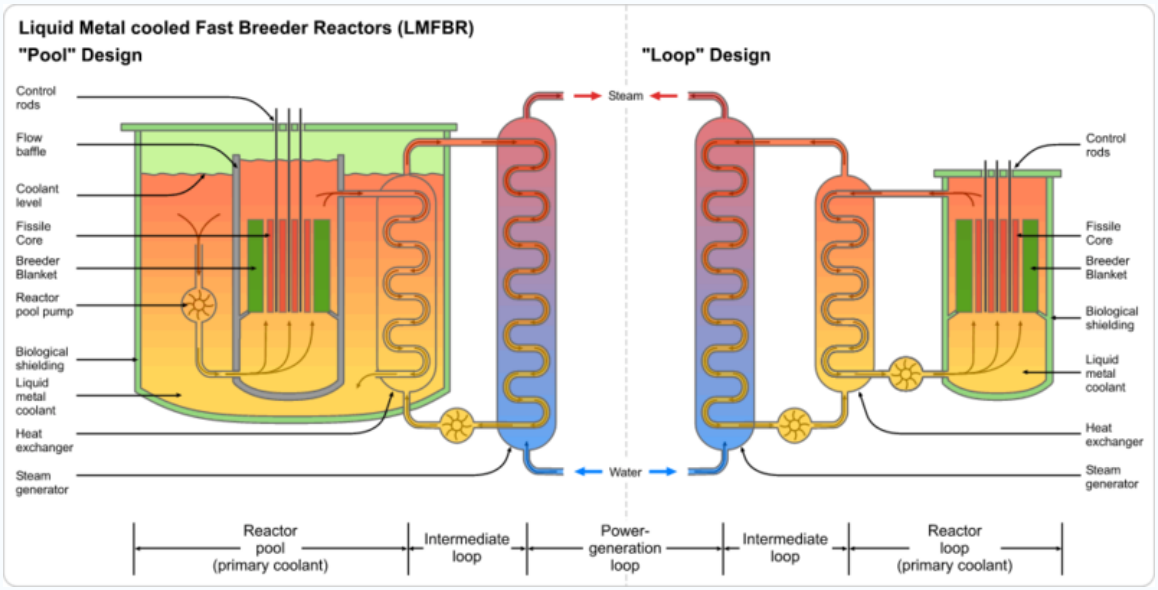


The bombardment of uranium-238 with neutrons triggers two successive beta decays with the production of plutonium. The amount of plutonium produced depends on the breeding ratio. (Nave, 2006)

C. Global Development of Breeder Reactors

Globally, the further development of breeder reactors is constantly growing. Japan, China, Korea, Russia, France, India, Germany, South Africa, Iran and the UK are advancing their technology. These advancements are very controversial due to the potential, but unlikelihood, for nuclear energy waste to be transformed into a nuclear bomb. There are several types of breeder generating plants. There are High Temperature Gas Cooled Reactors, Fast Breeder Reactor (FBR), Liquid Metal Fast Breeder Reactor (LMRBR), Thermal Breeder Reactors, Pressurized Heavy Water Reactor (PHWR), Advanced Heavy Water Reactor (AHWR), Sodium Cooled Fast Reactor, Liquid Fluoride Reactor and the Light Water Reactors; advanced boiling water reactor (ABWR) and advanced pressurized water reactor (APWR). (WNA, 2005a) All of these facilities and technologies can breed Pu but through different processes.

D. Original FBR Design



Loop vs Pool Design in a FBR (Wikimedia Foundation, Inc., 2006)

E. Liquid Fluoride Reactor

The modern Liquid Fluoride Reactor (Dean, 2006) was also developed as a thermal breeder. Liquid-fluoride reactors have many attractive features, such as deep inherent safety (due to their strong negative temperature coefficient of reactivity and their ability to drain their liquid fuel into a passively-cooled and non-critical configuration) and ease of operation. They are particularly attractive as thermal breeders because they can isolate protactinium-233 (the intermediate breeding product of thorium) from neutron flux and allow it to decay to uranium-233, which can then be returned to the reactor. Typical solid-fueled reactors are not capable of accomplishing this critical step in thorium conversion to energy.

F. Commitment to Future Developments of LMFBRs

Japan, China, Korea and Russia are all committing substantial research funds for the further development of LMFBR designed reactors. The US, UK, France, former USSR,

India and Japan have all built and operated FBRs. Germany built but never operated their FBR and in 2004 a prototype FBR was under construction in China.

G. Reactor History

1. United States

The US led the world with the first fast reactor in December 20, 1951. (National Academy of Engineering, 2006) Experimental Breeder Reactor -1 (EBR-1) was established at the Idaho National Laboratory in Idaho Falls, ID. This was a milestone in the development of nuclear power reactors. The world's first commercial LMRBR and the only one in the US was the 94MWe Unit 1 at Enrico Fermi Nuclear Generating Station is in Nuclear Regulatory Commission (NRC) Region Three between Detroit and Toledo. This was a joint effort of Dow Chemical and Detroit Edison furthering the Atomic Power Development Association consortium in 1956. This facility fluctuated in operation until August 1972 when its operating license renewal was denied.

2. Soviet Union

In 1955, the Soviet Union followed. In the Argonne National Laboratory's Reactor Analysis Division's study (as cited in International Nuclear Safety Center, 2006) reports a series of fast reactors, the first being mercury cooled and fueled with plutonium metal and the later plants sodium cooled and fueled with plutonium oxide. Unlike the US, their nuclear plans were well established. BN-350 (1973) was the first full-scale Soviet FBR. Constructed on the Mangushlak Peninsular in Kazakstan and on the shore of the Caspian Sea, it supplied 130MW of electricity plus 80,000 tons per day of desalinated fresh water to the city of Aktau. Its total output was regarded as the equivalent of 350MWe, hence the designation.

3. India

On October 18, 1985, India became the sixth nation to have the technology capable of building and operating a Fast Breeder Test Reactor (FBTR). India has taken a unique

approach to breeder reactors. India is the only country to use a Thorium only breeder. M. R. Srinivasan of The Hindu, India's National Newspaper, spoke of the nuclear developments in India in the September 17, 2003 edition. "India is the only country in the world that is committed to using thorium as a nuclear fuel and has, over the years, accumulated considerable knowledge on the various steps involved in thorium utilization." They are country rich in Thorium but low in Uranium. Almost a third of the world's thorium reserves are in India, which in contrast has less than 1% of the world's uranium.(Steffen, 2006) The FBR program of India includes the concept of using fertile Thorium-232 to breed fissile Uranium-233. India is also pursuing the thermal breeder reactor again using thorium. A thermal breeder is not possible with purely uranium/plutonium based technology. Thorium fuel is the strategic direction of the power program of India, owing to their large reserves of thorium, but worldwide known reserves of thorium are also some three times those of uranium.

H. India's Nuclear Power Generation Strategy

India has developed and mastered the technology to produce Pu rich U-Pu mixed carbide fuel for use in the FBR. India has the capability to use Thorium Cycle based processes to extract nuclear fuel. This is of special significance to the Indian nuclear power generation strategy as India, with the world's largest reserves of thorium (about 360,000 tons), can fuel nuclear projects for an estimated 2,500 years. However, Thorium is used in specially designed expensive AHWRs and Liquid Fluoride Reactors instead of their PHWRs currently in use. The US and India are in a nuclear energy cooperation deal. This deal consists of unique criteria which President Bush enunciated, such Nuclear Energy Cooperation with a non-signatory to the Nuclear Non-Proliferation Treaty.

I. CANDU Reactor

Canada's Atomic Energy Commission (AECL) has had two Heavy Water Reactor designs under development based on its reliable CANDU-6 reactor. The most recent of those reactors are currently operating in China.

> The CANDU-9 (925-1300 MWe) was developed from this also as a single-unit plant. It has flexible fuel requirements ranging from natural uranium through slightly-enriched uranium, recovered uranium from reprocessing spent PWR fuel, mixed oxide (U & Pu) fuel, direct use of spent PWR fuel, to thorium. It may be able to burn military plutonium or actinides separated from reprocessed PWR/BWR waste. A two year licensing review of the CANDU-9 design was successfully completed early in 1997. (AECL, 2006)

J. Reactor Developments and Advancements

South Africa's High Temperature Gas Cooled Reactor, the Pebble Bed Modular Reactor (PBMR) is being developed by a consortium led by the utility Eskom, and drawing on German expertise. France's first reactor was the loop-type of FBR built in 1967. In 1984, they introduced the world's largest FBR; the Super Phenix (Nave, 2006) which was shut down in 1997 due to political commitment of the left-wing government, to competitive market forces. The BN-600 (Beloyarsk NNP in the town of Zarechny, Sverdlovsk Oblast) is still operational. A second reactor (BN-800) is scheduled to be constructed before 2015. (Bellona, 2006) South Korea is developing a design for a standardized modular FBR for export, to complement the standardized PWR and CANDU designs they have already been developed and built, but has not yet committed to building a prototype. On February 16, 2006 the U.S., France and Japan signed an arrangement to research and develop sodium-cooled fast reactors in support of the Global Nuclear Energy Partnership. (Stevens, 2006)

The World Nuclear Association lists global developments:

> In Japan, the first two ABWRs, Kashiwazaki Kariwa-6 & 7, have been operating since 1996 and are expected to have a 60 year life. These cost about US$ 2000/kW to build, and produce power at about US 7c/kWh. A third unit started up in 2004. Future ABWR units are expected to cost US$ 1700/kW. Several 1350 MWe units are under construction in Japan and Taiwan. In South Korea, , the APR-1400 Advanced PWR design has evolved from the US System 80+ with enhanced safety and seismic robustness and was earlier known as the Korean Next-Generation Reactor. Design certification by the Korean Institute of Nuclear Safety was awarded in May 2003. The first of these 1450 MWe reactors will be Shin-Kori-3 & 4, expected to be operating about 2012. Fuel has burnable poison and will have up to 60 GWd/t burn-up. Projected cost is US$ 1400 per kilowatt, falling to $1200/kW in later units with 48 month construction time. Plant life is 60 years. In Europe, four designs are being developed to meet the European Utility Requirements (EUR) of French and German utilities, which have stringent safety criteria. In Russia, several advanced reactor designs have been developed - advanced PWR with passive safety features. (WNA, 2005a)

K. Growing Nuclear Breeder Market

There is a growing nuclear market. Uranium is being mined and Plutonium bred. Involved countries claim that its breeder production is strictly for energy related purposes. Many world governments and organizations fear that some countries like Iran (NTI, 2006) may have other intentions. The chart below clearly emphasizes the attraction and desire for nuclear breeders around the world. We must hope that this is not a facade for nuclear war but truly a desire for the new technologies that the industry has to offer including a reversal to global warming. (CEA, 2002)

ADVANCED THERMAL REACTORS being marketed

Country and developer	Reactor	Size MWe	Design Progress	Main Features (improved safety in all)
US-Japan (GE-Toshiba)	ABWR	1300	Commercial operation in Japan since 1996-7. In US: NRC certified 1997, FOAKE.	• Evolutionary design • More efficient, less waste • Simplified construction (48 months) and operation
USA (Westinghouse)	AP-600 AP-1000 (PWR)	600 1100	AP-600: NRC certified 1999, FOAKE. AP-1000 NRC design approval 2004.	• Simplified construction and operation • 3 years to build • 60-year plant life
France-Germany (Framatome ANP)	EPR (PWR)	1600	Future French standard. French design approval. Being built in Finland. US version being developed.	• Evolutionary design • High fuel efficiency • Low cost electricity
USA (GE)	ESBWR	1550	Developed from ABWR, under certification in USA	• Evolutionary design • Short construction time
Japan (utilities, Westinghouse, Mitsubishi)	APWR	1500	Basic design in progress, planned at Tsuruga	• Hybrid safety features • Simplified Construction and operation
South Korea (KHNP, derived from Westinghouse)	APR-1400 (PWR)	1450	Design certification 2003, First units expected to be operating c 2012.	• Evolutionary design • Increased reliability • Simplified construction and operation
Germany (Framatome ANP)	SWR-1000 (BWR)	1200	Under development, pre-certification in USA	• Innovative design • High fuel efficiency
Russia (Gidropress)	V-448 (PWR)	1500	Replacement for Leningrad and Kursk plants	• High fuel efficiency
Russia (Gidropress)	V-392 (PWR)	950	Two being built in India, Bid for China in 2005.	• Evolutionary design • 60-year plant life
Canada (AECL)	CANDU-6 CANDU-9	750 925+	Enhanced model Licensing approval 1997	• Evolutionary design • Flexible fuel requirements • C-9: Single stand-alone unit
Canada (AECL)	ACR	700 1000	ACR-1000 proposed for UK. undergoing certification in Canada	• Evolutionary design • Light water cooling • Low-enriched fuel
South Africa (Eskom, Westinghouse)	PBMR	165 (module)	prototype due to start building 2006	• Modular plant, low cost • Direct cycle gas turbine • High fuel efficiency
USA-Russia et al (General Atomics - OKBM)	GT-MHR	285 (module)	Under development in Russia by multinational joint venture	• Modular plant, low cost • Direct cycle gas turbine • High fuel efficiency

VII. NUCLEAR CURE TO GLOBAL WARMING

A. Energy Alternatives

Nuclear energy is the focus of tomorrow for many of our global neighbors. Still there are alternatives to nuclear electricity. Today the primary source of electricity generation is from fossil fuels, primarily coal. Half of today's global warming is due to 150 years of steadily increasing carbon dioxide in our atmosphere resulting from the burning of these fossil fuels.

> No technology is absolutely safe or without environmental effects. We should therefore compare the production of electricity from nuclear energy with the other options available to us. Burning coal in power stations is still the major source of electricity worldwide, followed by hydro, uranium and gas.
>
> A 1000 MWe light water reactor uses about 25 tonnes of enriched uranium a year, requiring the mining of some 50,000 tonnes of uranium ore. By comparison, a 1000 MWe coal-fired power station requires the mining, transportation, storage and burning of about 3.2 million tonnes of black coal per year. This creates around 7 million tonnes of carbon dioxide not to mention sulfur dioxide, depending on the particular coal. Solid wastes from a coal-fired power station can be substantial and cause environmental and health damage. (UIC, 2006)

B. Cost of Nuclear Power

Nuclear energy claims to be inexpensive. Most proposals will display this very fact however, William Sweet (2006) author of "Kicking the Carbon Habit: Global Warming and the Case for Renewable and Nuclear Energy" disagrees.

> Clearly, then, nuclear energy - from a resource stand point - can at best be a stop gap solution to the energy needs of the world. From a cost stand point, it does not compare favorably with other alternatives today and as the British case shows, vested interests have often engaged in deceitful practices to present it as feasible. In any case, even in these examples, the costs do not include the cost of decommissioning, close down and disposal of nuclear waste - all of which are huge. An update on huge nuclear plant decommissioning costs was reported in The Guardian Weekly, 12/8/05, with Paul Brown, writing that costs of cleaning up more than 50 years of Britain's nuclear waste had risen by £8bn to £56bn and will rise further. In addition, the process results in the build up of millions of tons of radioactive and contaminated wastes that we still do not have a way of disposing.

C. Nuclear Progress in the United States

Professor Emeritus Bernard L. Cohen (1990) of the University of Pittsburgh and author of multiple documents and books on nuclear power, radiation and plutonium offers information that rebuts Mr. Sweet's claims.

> The United States could get along for the foreseeable future with coal. It would be more expensive as well as much more harmful to our health and to the environment, but we could get by. For other countries, the situation is much less favorable. Western Europe and Japan have relatively little coal, and will therefore sorely need nuclear power when the oil runs out or is withdrawn for political or economic reasons. For them, nuclear power is much cheaper than any other alternatives. With present reactors, we can continue building plants for about another 30 years and still be able to guarantee each a lifetime supply of fuel. Beyond that we will have to convert over to breeder reactors. With that technology, our fuel supply will last forever without affecting the price of electricity.

President Bush has an aggressive strategy for the progression of nuclear energy. The Bush Energy Plan calls for doubling the number of nuclear reactors in the US by 2040.

> "There are over 130 nuclear reactors under construction, planned or under consideration around the world today. The U.S. has not ordered a nuclear power plant in over 30 years and we have 103 nuclear power plants in this country. We have more than any other country, but we have not built one in about 30 years. And so we are anxious to get back into the nuclear generation business ourselves." (GNEP, 2006)

VIII. DISPOSAL OF NUCLEAR BY PRODUCTS

A. US Waste Disposal Sites

Disposal of radioactive by products is a tough subject. If we are to increase our nuclear energy production, disposal of it's by products has to be addressed. Yucca Mountain is slated to be America's nuclear waste disposal facility. Professor Cohen mocks those that claim we can not bury our waste by comparing the US populace to a canine. "Even a dog can bury his bone." Professor Cohen reminds us that the glass spheres or spent rods in their encasements do not require the expense, sophistication and political extravaganza of the Yucca Mountain Project for safety. It is waste and therefore can be buried and disposed of as such.

Opponents of the project will remind you that Yucca Mountain is only designed to contain the waste from existing reactors. Proposed recycling would extend the ability of the mountain to receive waste for generations to come. Expanding our nuclear energy capacity or not; we still have the wastes of yesterday to properly dispose. Either way, our politicians are guiding us toward Nuclear Energy. Having an oil barren directing this push, I attest more weight to the economic advantages of nuclear power than to Mr. Sweet's disadvantages.

Specific transport vessels and plans are in place for the Waste Isolation Pilot Plant (WIPP), Yucca Mountain Project and all other transport of radioactive waste. Yucca Mountain is the US's proposed nuclear waste graveyard**.** Yucca Mountain was planned for high level wastes from commercial nuclear electric generating reactors. Superfund site clean up and transuranic wastes are slated to reside at the WIPP in New Mexico. This 35 year project (EHC, 1997), begun in 1999, moved transuranic waste from storage to a permanent disposal site in NM. Reports vary but stage two, if implemented, would include remote-handled wastes from nuclear test sites.

> Some TRU waste also contains activation materials and fission products that decay by beta emission and produce penetrating gamma radiation. This waste is referred to as "remote handled" (RH) if the radiation level at the surface of the packaging exceeds 200 millirem per hour. About 5 percent of the total TRU waste shipped to WIPP will be RH TRU. Unlike the TRUPACT-II, the shipping containers for RH TRU waste will require heavy shielding. DOE currently has no plans to ship any RH TRU waste from NTS to WIPP. (State of Nevada Nuclear Waste Project Office, 1998)

Major Radionuclides Present in the TRU Waste at NTS (Nuclear Test Site)

Major Radionuclides	Percent by Weight	Percent by Activity
Plutonium-238	Trace	3.51
Plutonium-239	93.55	63.11
Plutonium-240	5.89	25.37
Plutonium-241	0.54	8.00
Plutonium-242	Trace	0.01
Americium-241	Trace	Trace
Total	99.98	100.00

A Mutual Consent Agreement with the State of Nevada would allow DOE to store certain other wastes, such as NTS cleanup wastes classified as mixed low-level or mixed TRU waste, on the TRU waste pad. (State of Nevada Nuclear Waste Project Office, 1998)

1. Public Fears

The establishment of these disposal facilities has heightened public awareness. Politicians are divided on their stand and much controversy has ensued over America's nuclear waste and nuclear energy programs. Terrorists' threats, transportation issues, storage issues, potential contamination from leakage and long term effects to the area from radioactive storage has spurred many mixed demonstrations.

2. Yucca Mountain Project

Opponents to continued nuclear energy programs and/or the Yucca Mountain Project remind their listeners that Yucca Mountain is only able to hold 77,000 tons of high-level radioactive nuclear waste, the amount of nuclear waste currently in commercial reactors. However, these reactors will continue to produce more waste and they claim that Yucca Mountain won't be able to contain it due to capacity restrictions. Additionally, the immediate risk of local storage of nuclear waste will not disappear upon the opening of Yucca Mountain. Transport of the current waste is slated over a 24-year period.

3. Fear of Terrorist Actions

Homeland Security, after 911, has raised everyone's awareness of terrorism. Terrorists could create a "dirty bomb" however, as Professor Cohen (1990) points out, if killing 50,000 people is the terrorists' desire, there are many easier alternatives for accomplishing their objective. "Dirty bombs", rarely cause massive destruction.

Terrorists generally desire dramatic effects. To obtain such; they could:

- Release a poison gas into the ventilation system of a large building.
- Dynamite the structural supports in a sports stadium so as to drop the upper tier down on top of the lower tier; this should kill nearly all the people in both tiers.

- Discharge a large load of napalm (or perhaps even gasoline) on the spectators in a sports stadium, either by airplane or truck.
- Blast open a large dam; there are situations where this could kill over 200,000 people.
- Poison a city water or produce supply.

4. Government Control over Nuclear Technology

What we need to remember is that these shipments will be under strict government control and that nuclear power plants and waste storage facilities have very elaborate security measures. Sabotaging a nuclear plant effectively would require a considerable amount of technical knowledge and a substantial quantity of explosives. Should terrorists take over a nuclear plant, "In principle, they could cause a very bad accident, thereby killing tens of thousands of people, including themselves. However, nearly all of their victims would suffer no immediate effects, but rather would die of cancer 10 to 50 years later. In view of the high normal incidence of cancer, these excess cases would be unnoticeable. This would hardly serve the purposes of terrorist." (Cohen, 1990) What Pu the terrorists may steal would be of poor quality for the purpose of nuclear weapons. "A nation desiring nuclear weapons would find it much cheaper, faster, and easier to produce the plutonium in other ways. This would also give their bombs higher explosive power and much improved reliability." (Cohen, 1990) Furthermore, in the current US nuclear power industry there is no material present that could be used for making nuclear bombs. Recall, Pu is "born" in a breeder. The US does not currently have any operational breeders that produce Pu.

B. Possibility of Nuclear Bomb Constructed from Reactor Plutonium

Sutcliffe and Trapp (1994) through the Lawrence Livermore National Laboratory address the disadvantages of "reactor-grade" Pu in the construction of a nuclear bomb. They acknowledge that it is a very complex project in design, fabrication and handling. Pu would have to be handled very rapidly to prevent pre-initiation.

> Hence the simplest type of nuclear explosive, a "gun type," in which the optimum critical configuration is assembled more slowly than in an "implosion type" device, cannot be made with plutonium but only with highly enriched uranium, in which spontaneous fission is rare. This makes HEU [Highly Enriched Uranium] an even more attractive material than plutonium for

> potential proliferators with limited access to sophisticated technology. Either material can be used in an implosion device.

Even if we choose to not advance our nuclear energy program; we still have the waste for our past efforts to dispose. Despite much opposition, the Yucca Mountain Project is forging ahead. The risks must be addressed and properly handled to minimize the hazard. Richard L. Garwin, Senior Fellow for Science and Technology Council on Foreign Relations' address in August 1998 in New York brought these fears to a clear conclusion.

> In conclusion, separated plutonium - whether weapon grade or reactor grade - poses a similar danger of misuse in nuclear weapons and must be provided similar physical protection, control, and accountancy. This has been recognized by the International Atomic Energy Agency (IAEA) from its beginning - all plutonium (except Pu-238 of isotopic purity greater than 80%) is regarded as equally hazardous from the point of view of diversion to nuclear weaponry. (Garwin, 1998)

IX. RECYCLING

A. Minimization of Waste or Nuclear War?

Separated Pu poses the highest risk in the nuclear power industry. Pu recovery is a very heated political and international issue. Many of the world's organizations view Pu recycling and breeding as a means to conceal nuclear capability for weapons. Environmentally conscience nations, view recycling as a means to minimize waste that needs to be buried and an unlimited means to produce electricity.

B. President Bush Establishes Recycling Budget

Spent rods are recycled in other countries. This is a plan that the US needs to adapt. President Bush believes in nuclear recycling and has earmarked a $250M budget for nuclear fuel-reprocessing. (Bellona, 2006) Recycling consists of dissolving and chemically separating uranium, plutonium and high-level waste. Through recycling, nuclear energy would be a viable renewable source of clean energy. "About 97% of the spent fuel can be recycled leaving only 3% as high-level waste. The recyclable portion is

mostly uranium depleted to less than 1% U-235, with some plutonium, which is most valuable." (UIC, 2006) The Uranium Information Center in Australia explains what has been achieved in 35 years and over 55,000 tons of spent fuel recycling.

> Arising from a year's operation of a typical l000 MWe nuclear reactor, about 230 kilograms of plutonium (1% of the spent fuel) is separated in reprocessing. This can be used in fresh mixed oxide (MOX) fuel (but not weapons, due its composition). MOX fuel fabrication occurs at 5 facilities in Europe, with some twenty years of operating experience. The first large-scale French and UK plants started up in 1995 and 2001 respectively. Across Europe, over 35 reactors are licensed to load 20-50% of their cores with MOX fuel.
>
> The 3% of the spent fuel which is separated high-level wastes amounts to 700 kg per year and it needs to be isolated from the environment for a very long time. These liquid wastes are stored in stainless steel tanks inside concrete cells until they are solidified. (UIC, 2006)

C. Reduction of Waste

The immobilized high-level waste is then solidified, a process developed in France, UK, US and Germany over the past 35 years. The small globes of waste would greatly reduce the disposal issue and expand the duration of our waste facilities.

> Liquid high-level wastes are evaporated, mixed with glass-forming materials, melted and poured into robust stainless steel canisters which are then sealed by welding. A piece this size would contain the total high-level waste arising from nuclear electricity generation for one person throughout a normal lifetime. (UIC, 2006)
>
> A more sophisticated method of immobilizing high-level radioactive wastes has been developed in Australia. Called 'SYNROC' (synthetic rock), the radioactive wastes are incorporated in the crystal lattices of the naturally-stable minerals in a synthetic rock. In other words, copying what happens in nature. This process is now being tested in USA. (UIC, 2005)

X. CONCLUSION

Despite the potential health hazards, risk-benefit analysis shows that nuclear energy is the way to future electrical production. Nuclear energy is widely used in Europe and Asia. India is experimenting with Thorium breeder technology. America is falling behind. We must adapt to the ways of the new millennium. Fossil fuels are fading. Educating ourselves on Pu will remove the unfounded fears. If we handle Pu with respect; we can all benefit from its properties instead of suffer from their hazardous potential.

It is "fiction that conservation, solar panels and windmills alone can meet human needs. Sustainability requires nuclear energy; and the path of sound environmentalism today is to embrace, fight for - and finance - a future in which nuclear power and "new renewables" function as clean-energy partners in a transformed global economy." (Ritch, 2004)

Hydricity, so dubbed by the father of the hydrogen-fuel cell, Geoffrey Ballard, is an exciting new technology that allows hydrogen to "provide a bridge by which nuclear power can contribute not just to base-load electricity but to the entire spectrum of energy use. With this bridge, it is now possible for the first time to envisage a thriving, large-scale, emissions-free industrial economy - with nuclear power and renewables providing clean primary energy for direct electricity and for electricity storage via hydrogen." (Ritch, 2004) This new technology is globally accepted. Reinstating our nuclear energy plans and recycling will reduce our dependency on other countries for fossil fuels. This inexhaustible source of energy will provide for generations to come and reduce greenhouse gases simultaneously. Pu will be a source of energy and not a source of death or destruction.

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