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Nuclear Power, Radiation, and Disease

Few, if any, estimates of the costs of nuclear energy take into account the health costs to the human race. Even when nuclear power plants are operating normally, these costs are not insignificant. Miners, workers, and residents in the vicinity of the mining and milling functions, and workers involved in the enrichment processes necessary to create nuclear fuel are at risk for exposure to unhealthy amounts of radiation and have increased incidences of cancer and related diseases as a result. Routine and accidental radioactive releases at nuclear power plants as well as the inevitable leakage of radioactive waste will contaminate water and food chains and expose humans and animals now and for generations to come. Accidents such as Three Mile Island and Chernobyl condemn thousands if not millions to pay the cost of nuclear power with their own health. Understanding the nature of radiation is critical to understanding the health impacts of nuclear energy.

RADIATION AND EVOLUTION

Billions of years ago the earth was relatively radioactive and hostile to life, as radiation emanated both from the terrestrial plane—rocks and soil—and from powerful solar radiation in space. The solar effect was much more intense at that time, because the ozone layer that filters out the carcinogenic ultraviolet radiation from the sun was almost non-existent. Over billions of years, as plants developed and evolved, they generated oxygen (O_2) from photosynthesis, which rose up through the lower layers of atmosphere into the stratosphere, where it was converted to ozone (O_3) by ultraviolet light. Gradually, as the ozone layer accumulated in the upper atmosphere, the intensity of the solar radiation diminished, as did the terrestrial radiation, and the earth "cooled down."

Life began as primitive single-celled organisms, which, over billions of years evolved into many and varied multicellular organisms. Human beings appeared relatively recently—only 3 million years ago. Background radiation was one of the main instigators of evolution, as it induced mutations in the reproductive DNA molecules or genes of plants and animals. (A mutation is a biochemical change in the double helix DNA molecule.) The vast majority of mutations were "deleterious," causing death and disease in the offspring, but some were "advantageous," allowing the new organisms to flourish in a hostile and difficult environment. Fish developed lungs and climbed out of the water to become land-dwelling amphibians, dinosaur-like creatures developed wings, and became the earliest form of birds, and humans evolved as our predecessors stood on their hind limbs, grew the opposing thumb, and developed a huge cerebral neocortex—changes that eventually allowed us to dominate and control the natural environment. As the earth cooled down and background radiation decreased, genetic mutations decreased in frequency, and species adjusted to this change.

Radiation, which has been fundamental to the evolution of planetary life, is largely responsible for development of the most extraordinary and wonderful variety of living species over a time frame of billions of years. But humans seem determined to alter this stable balance bequeathed to us by nature. With only the barest comprehension of evolution or the delicate process of genetics, we create massive quantities of radioactive elements to power our "lifestyle" because we are attached to ever-increasing levels of technological progress, prosperity, luxury, and ease of living.

When humans succeeded in splitting atoms, they also embarked upon a process that would inevitably increase the levels and diversity of background radiation on the earth. The process of fissioning uranium in nuclear reactors creates more than 200 new, man-made radioactive elements. Some "live" for only seconds; some remain radioactive for millions of years.

Once created, these diabolical elements will inevitably find their way into the environment and will eventually enter the reproductive organs of plants, animals, and humans, where they will mutate the genes in reproductive cells to cause disease and death in the immediate generation or pass a hidden genetic disease to distant offspring down the time track. This is because, as explained above, most mutations cause disease, whereas advantageous mutations are infrequent and require millions of years to express themselves.

RADIATION AND HUMAN REPRODUCTION

As many of us have learned in biology courses, genes are composed of DNA molecules, which are the very building blocks of life, responsible for every inherited characteristic in all species—plants, animals, and humans. Every gene in an egg or sperm is precious and unique. When the egg and sperm are created, the number of genes in each reproductive cell is halved, so that when conception occurs, the new individual has a full complement of genes. Most characteristics are governed by a pair of genes, one inherited from the mother, and one from the father. Each of these genes can be either dominant or recessive.

The characteristics of dominant and recessive genes are well demonstrated by eye coloring: Brown-eyed genes are dominant and blue-eyed genes are recessive. Blue eyes can manifest only if a person inherits of *pair* of blue-eyed genes—this individual is homozygous for blue eyes. Brown-eyed people can be either homozygous with two brown-eyed genes or heterozygous with a brown- and a blue-eyed gene. If, for example, the mother has blue eyes and the father is homozygous for brown eyes, all offspring will be brown eyed because all the sperm will carry the brown-eyed gene. But if the father is heterozygous, the baby has a 50% chance of having brown eyes, because half the sperm will carry the blue-eyed gene and half the brown-eyed gene.

The same holds true for many inherited diseases. Cystic fibrosis (CF), the most common lethal genetic disease of childhood, is inherited as a recessive gene. One in twenty-five people of Caucasian descent carry this recessive gene. When two CF carriers mate, there is a one in four chance that two CF genes will unite to produce an offspring with CF, that is, one fetus will be homozygous for two normal genes, two will be heterozygous for a normal gene and one for CF, and one will be homozygous for two recessive CF genes.

All people carry recessive genes for disease, but not until a person mates with another carrier of one of their abnormal genes can a baby be born manifesting this disease. The majority of these abnormal genes have been caused by mutations in the distant past—usually by background radiation, although some new mutations do arise spontaneously.

The seminal work on radiation and genetics was performed in 1927 by Dr. H.J. Muller, who irradiated drosophila fruit flies. Because these flies reproduce very rapidly, Muller could observe the effects on hundreds of generations within a short space of time. For instance, a radiation-induced dominant mutation that caused a crooked wing would be passed down through many generations of fruit flies. Dr. Muller was awarded a Nobel Prize for his pioneering work. Other researchers have since verified Muller's findings, and the number of mutations has been shown to be in direct ratio to the cumulative amount of radiation received by the reproductive organs, be it a single large dose or many smaller doses.

Radiation induces mutations that are either dominant, recessive, or sex linked—carried on the female X chromosome or in cellular mitochondria, which determine some genetic characteristics. Many conditions such as diabetes, cystic fibrosis, muscular dystrophy, and certain forms of mental retardation are recessive diseases. Two typical sex-linked genetic diseases are color blindness and hemophilia. There is a total of 16,604 genetically inherited diseases now described in the literature.[1]

All human cells have forty-six chromosomes in their nucleus, and genes themselves are arranged in pairs along twenty-three pairs of chromosomes. Apart from *genetic* mutations, radiation can cause breaks in *chromosomes*, which can cause a baby to be born with Down's syndrome or some other serious mental or physical disorders. A normal fetus with fully functioning genes and chromosomes can also be damaged by external radiation exposure or if a radioactive element crosses the placenta and lodges in the fetus, killing a particular cell that would later form the septum of the heart, the right half of the brain, or the left arm, for example. This pathological process, which results in malformations of the heart, the brain, the limbs, or other organs of a fetus, is called teratogenesis. Similar deformities were observed in decades past when pregnant women took the drug thalidomide—which likewise killed important cells within the fetus—to alleviate their morning sickness.

RADIATION AND DISEASE

All non-reproductive or "somatic" body cells have regulatory genes that control the rate of cell division. If a regulatory gene is biochemically altered by radiation exposure, the cell will begin to incubate cancer, during a "latent period of carcinogenesis," lasting from two to sixty years. Then one day, instead of the cell dividing into two daughter cells in a regulated fashion, it will begin to divide in a random, uncontrolled fashion into millions and trillions of daughter cells, creating a cancer. Cancer cells tend to be very invasive. They break off from the main cancer mass, invading lymph vessels and blood vessels in a microscopic fashion, and travel to other organs (liver, bone, lung, brain, etc.) where they grow into secondary cancers or metastases. In many cases it is difficult if not impossible to stop this random growth of abnormal cells. Thus, a single mutation in a single gene can be fatal.

It is thought that 80% of cancers that we see are caused by environmental factors, whereas only 20% are inherited. Cancer has always plagued the human race; some ancient Egyptian mummies were riddled with cancers. It is generally accepted that many cancers in the past and in the present have been and are caused by background radiation. Because aging exposes people to increasing doses of radiation and carcinogenic chemicals, cancer is generally a disease of old age.

However, no dose of radiation is safe, and all radiation is cumulative. Each dose received adds to the risk of developing cancer or mutating genes in the reproductive cells. (The risk is small and the benefit great when a serious diagnosis must be made, but exposure to unnecessary X-rays or CAT scans must be avoided.) We are exposed to a background radiation dose of about 100 millirems per year from the earth and the sun. It has been estimated that if one hundred and twenty-five people receive 100 millirems per year for seventy years, one of them will develop cancer. But the Nuclear Regulatory Commission (NRC), which is responsible for the oversight of the nuclear power industry, has decided that it is acceptable for the public to receive an additional 100 millirems per year from man-made radiation created through the generation of nuclear energy, meaning two extra cancer patients will be created out of every hundred people annually, adding together the one cancer from background and one from "allowable" man-made radiation.[2]

The rules are even more lenient for nuclear workers, who are allowed doses of 5 rems per year (5,000 millirems). One in five nuclear workers are predicted to develop cancer if they received this "legally allowable" dose over fifty years of exposure.[3] These workers have to operate in areas that are very radioactive or "hot," exposing their reproductive organs to radiation. Because most nuclear workers are men, mutated genes in their sperm will be inherited by their offspring and passed on to future generations. The few women nuclear workers will be similarly affected as genes mutate in their eggs. The nuclear industry cannot function without these dangerous exposures, but one wonders if any nuclear workers are adequately informed about the biological dangers of working in the nuclear industry.

Furthermore, when the nuclear industry calculates "acceptable" radiation exposure for the public, they use a model of a standard, healthy 70 kilogram man. But the population is far from homogeneous. Old people, immuno-depressed patients, normal children, and some with specific, inherited diseases are many times more susceptible to the deleterious effects of radiation than normal adults. Overall, about forty-two people out of hundred are expected to develop cancer in their lifetimes from all causes. Children born to parents who have been exposed to radiation have a higher-than-normal risk of developing cancer or leukemia.[4] High levels of radiation are also known to cause heart disease and strokes.[5]

The incidence of cancer in adults is on the rise,[6] particularly cancers of the kidney, brain, and liver; non-Hodgkin's lymphoma; and testicular cancer. Children have experienced an elevated cancer incidence as well, particularly of brain cancers,[7] as we pollute the environment with carcinogenic chemicals and radioactive elements. Eighty thousand different chemicals are in common use, very few of which have been tested for carcinogenicity. Chemicals and radioactive elements tend to act synergistically in human and animal bodies—one will potentiate the carcinogenic effect of the other.

According to a National Academy of Sciences report,[8] man-made radiation in the United States accounts for 18% of human exposure. Other sources of radiation include exposure to naturally occurring radioactive radon gas, to radioactive rocks and minerals on the earth, and to ultraviolet radiation from the sun. Of the man-made category, medical X-rays and nuclear medicine (short-lived radioactive elements used in diagnostic examinations and for the treatment of some cancers) account for about 79%, whereas radioactive elements in consumer products such as tobacco, tap water, and nuclear power currently account for 5%.[9] But this is now. As the huge quantities of radioactive waste accumulating from nuclear power and from nuclear weapons production start leaking and contaminating drinking water and food chains in many parts of the world, so the percentage of radiation exposure from these sources will rise.

In summary, the 18% human exposure attributable to man-made radiation will increase, because radioactive waste remains potent for hundreds and thousands of years. So by turning on our lights today, we bequeath our descendants a radioactive legacy for tomorrow.

ROUTINE RADIATION FROM NUCLEAR POWER PLANTS

Before we consider radioactive elements that are released from the nuclear fuel cycle, we must first define what kind of radiation they emit and what sort of damage they may do to living cells. Each radioactive element or isotope is unique in its physical properties and has a specific half-life. For example, radioactive iodine 131 has a half-life of eight days, so that in eight days it loses half its radioactive energy, in another eight days it decays again to one quarter of the original radiation, ad infinitum. It is customary to multiply a half-life by roughly twenty to calculate the time that a particular isotope will retain its radiation. In the case of iodine 131, its radioactive life therefore is 160 days or twenty-three weeks.

Some isotopes made in a nuclear reactor have very short half-lives (less than a second) and some extremely long (millions of years). These isotopes also emit several types of radiation. Many emit gamma radiation, which is akin to X-rays. Gamma radiation goes straight through human bodies. It does not make a body radioactive, but as gamma rays pass through the body, they can mutate regulatory or reproductive genes.

Some of the new isotopes emit alpha radiation, which is a particle composed of two protons and two neutrons shot out from an unstable atomic nucleus. The nuclear industry has said that alpha radiation is not dangerous because it doesn't travel very far and can be stopped by a piece of paper. Likewise it does not penetrate the layers of dead cells in the human skin or epidermis to damage living cells. However, if it enters the body through the gastrointestinal tract or is inhaled into the lung, it comes into direct contact with living cells and, as such, is extremely mutagenic.

Other isotopes emit beta radiation, which is composed of an electron shot out from an unstable nucleus. Beta radiation travels farther than alpha because it is lighter. It too is very mutagenic and carcinogenic.

The radiation given off by isotopes is insidious and cryptogenic (hidden). Various radioactive elements become incorporated into specific organs of the body. For instance, if you inhale one-millionth of a gram of the alpha emitter plutonium, a very small volume of cells in the lung is irradiated because of the very short distance travelled by the alpha particle. Because alpha radiation is so deadly, most of the cells within the radiation field will be killed, but as radiation decreases with the square of the distance, cells on the periphery of the radiation field remain viable. Some of them almost certainly will suffer mutation of their regulatory genes, and cancer will later develop in one of these damaged cells.

There are many routes of exposure to man-made radiation from the nuclear industry. Relatively small but significant amounts of radiation are released on a daily basis into the air and water during the course of mining, milling, and enriching uranium for fuel to create the nuclear energy. Additionally, a nuclear power plant cannot operate without routinely releasing radioactivity into the air and water through the normal operation of nuclear reactors. Finally, and most frighteningly, accidental releases of even more radiation are commonplace in the nuclear industry.

Uranium Mining

Uranium mining began in Europe in the late part of the nineteenth century when Madam Curie was refining pitch blend from uranium ore and separating radium. Large-scale mining commenced sixty-five years ago specifically to provide fuel for nuclear weapons and continued unabated for many decades thereafter. Over one-half of all uranium deposits lie under Navajo and Pueblo tribal land, in the United States[10] and over the years, large numbers of Native Americans have been employed as below-ground and above-ground miners.

People who mine uranium below the ground are at great risk because they are exposed to a high concentration of radioactive gas called radon 220, which accumulates in the air of the mine. Radon is a daughter or decay product of uranium and is a highly carcinogenic alpha emitter, which, if inhaled, can decay in the lung and deposit in the air passages of the lung, irradiating cells that then become malignant. As a result, uranium miners have suffered from a very high incidence of lung cancer. One-fifth to one-half of the uranium miners in North America, many of whom were Native Americans, have died and are continuing to die of lung cancer.[11] Records reveal that uranium miners in other countries, including Germany, Namibia, and Russia, suffer a similar fate.[12]

Another lethal uranium daughter is radium 226, which is an alpha and gamma emitter with a half-life of 1,600 years. This radioactive element is notorious in the medical literature. In the early part of the twentieth century, women painted numbers on watch dials with radium enriched paint, so that the numbers glowed in the dark with radioactivity. To make the figures precise, they licked the tips of the paint brushes, thereby swallowing large amounts of radium. Because radium is a calcium analogue, it deposited in their bones. Many of these women subsequently died of osteogenic sarcoma, a highly malignant bone cancer affecting their facial bones, whereas others succumbed to leukemia, because white blood cells are manufactured in the bone marrow. Uranium miners are exposed to a similar risk because radium is an integral component of uranium dust in the mine. When they swallow the dust, radium is absorbed from the gut and deposits in their bones. Uranium itself also deposits in bone, and it too is carcinogenic.

Uranium ore also emits gamma radiation, which emanates from the ore face. So the miners are also exposed to a constant, whole-body radiation (like X-rays) emitted by other uranium daughters, which irradiates their bodies and continuously exposes their reproductive organs.

As the uranium ore is mined and the uranium is extracted, large quantities of radioactive dirt and soil are discarded and left lying in huge heaps adjacent to the mine, exposed to the air and the rain. This material is called tailings. Most tailings in North America are situated on indigenous tribal land of the Navajo nation and the Laguna Pueblo in New Mexico and on the Serpent River First Nation in Ontario, Canada. By 1980, the sovereign Navajo nation had forty-two uranium mines and seven mills located on or adjacent to reservation or trust land. Millions of tons of radioactive dirt constantly leak radon 220 into the air, exposing the indigenous populations who live nearby. As they inhale the radon, many of these people have developed or are developing lung cancer.[13]

Rain also leaches soluble radium 226 through the tailings piles into the underground water,[14] which is often the source of drinking water. When radium enters streams and rivers, it bio-concentrates tens to hundreds of times at each step in the food chain of the aquatic life and terrestrial plants. Because it is tasteless and odorless, people in these contaminated populations cannot tell whether they are drinking radioactive water, breathing radioactive air, or eating fish or food that will induce bone cancer or leukemia.

Hundreds of mines and tailings heaps lie exposed to the air and wind on Navajo land. Thousands of Navajos are still affected by uranium-induced cancers and will continue to be so for thousands of years unless remediation takes place.[15] In total, 265 million tons of uranium tailings pollute the American Southwest.[16] Neither the government nor the nuclear industry has ever attempted to clean up this massive radioactive pollution of tribal land. It is hard to imagine, however, similar piles of radioactive tailings lying adjacent to the well-heeled town of New Canaan, Connecticut, or near the Rockefeller estate in the Adirondacks.

Uranium Milling

The U.S. federal government covers the cost of milling uranium, the process by which the mined ore is crushed and chemically treated to convert the uranium metal into a compound called yellow cake. As in the mining process, the waste ore is discarded on the ground, primarily on Navajo tribal land in the American Southwest, where the government mills are situated. These mill tailings contain radium and a dangerous radioactive element called thorium—a uranium daughter and an alpha and gamma emitter with a half-life of 80,000 years. Over the last forty years, over 100 million tons of mill tailings have accumulated mainly in the Four Corners area (the intersection of Arizona, Colorado, New Mexico, and Utah) in the American Southwest.[17]

In the mid-1960s, local contractors at Grand Junction in Colorado discovered acres of discarded mill tailings, unguarded and untreated. Not knowing they were radioactive, the contractors used them for cheap landfill and in concrete mix. Schools, hospitals, private homes, roads, an airport, and a shopping mall were constructed using this material. In 1970, local pediatricians noticed an increased incidence of cleft lip, cleft palate, and other congenital anomalies among newborn babies born to parents who lived in these radioactive structures, which continually emitted gamma radiation and radon gas.[18]

The EPA allocated monies to the University of Colorado Medical Center to study the correlation between the birth defects and the radioactive dwellings. However, one year into the study, funds were abolished because federal authorities claimed that the government had to cut back on many programs for budgetary purposes.[19]

Uranium Enrichment

As described in chapter 1, the uranium 235 isotope is enriched from a low concentration of 0.7% to 3% for fuel in nuclear power plants. (If uranium 235 is enriched above a concentration of 50%, it can be used as nuclear weapons fuel.) Workers at all stages of the enrichment process are exposed to whole-body gamma radiation from by-products of uranium decay. But the most serious aspect of enrichment is the material that is discarded: uranium 238. This is called "depleted uranium" (DU) because it has been depleted of its uranium 235. But it is not depleted radioactively.

Depleted uranium is lying around in thousands of leaking, disintegrating barrels at the enrichment facilities in Paducah, Kentucky; Oak Ridge, Tennessee; and Portsmouth, Ohio. At Padacah alone, some 38,000 cylinders of DU await disposal. DU has contaminated the ground water, forcing the government to provide alternative drinking water for the local residents.[20]

The Pentagon, however, has found a nifty use for at least a small amount of this radioactive waste. Because uranium 238 is 1.7 times more dense than lead, it has been deemed the ideal antitank weapon. When shot out of a cannon, the solid uranium antitank shell cuts through the steel on the other fellow's tank like a hot knife through butter. But DU has several unfortunate properties. It is pyrophoric, which means that it bursts into flame upon impact, and when it burns, up to 80% disintegrates into finely powdered aerosol, which is distributed to the four winds. The mist is radioactive, and it has a half-life of 4.5 billion years.

Uranium is a heavy metal. It enters the body via inhalation into the lung or via ingestion into the GI tract. It is excreted by the kidney, where, if the dose is high enough, it can induce renal failure or kidney cancer. As a calcium analogue, it lodges in bones where, like plutonium, it causes bone cancer and leukemia. Last but not least, it is excreted in the semen, where it mutates genes in the sperm.

In the 1991 Gulf War invasion, the Pentagon used 360 tons of depleted uranium in the form of antitank shells in Iraq, Kuwait, and Saudi Arabia.[21] In the invasion that began in 2002, the United States and its allies have already deployed well over 127 tons, according to the Pentagon, which is loath publicly to announce the total amount of DU used. I suspect the actual quantities are significantly higher. Much of the DU is in cities such as Baghdad, where half the population of 5 million people are children who play in the burned-out tanks and on the sandy, dusty ground. Children are ten to twenty times more susceptible to the carcinogenic effects of radiation than adults. My pediatric colleagues in Basra, where this ordnance was used in 1991, report a sevenfold increase in childhood cancer and a sevenfold increase in gross congenital abnormalities.

In essence, the two Gulf wars have been nuclear wars because they have scattered nuclear material across the land, and people—particularly children—are condemned to die of malignancy and congenital disease essentially for eternity. Because of the extremely long half-life of uranium 238, the food, the air, and the water in the cradle of civilization have been forever contaminated.

It is important to note that other countries involved in uranium enrichment include Britain, China, Russia, Israel, Japan, Germany, Argentina, France, North Korea, Iran, Pakistan, Brazil, and India. Iran is not building nuclear weapons now, and the scale of North Korean and Israeli enrichment programs is not clear. Britain, China, Russia, France, and Pakistan have highly-enriched uranium weapons. Many of these other countries, if they so desired, could make nuclear weapons by enriching their uranium beyond 50%. America set the example years ago, and the world follows.[22]

Fuel Fabrication

The fabrication of nuclear fuel involves more human exposure to radioactive materials. After milling, the uranium fuel is made into cylindrical ceramic pellets the size of a cigarette filter and placed in hollow zirconium fuel rods, half-an-inch thick and twelve-to-fourteen feet long. Each rod contains at least 250 pellets. About 50,000 of these rods are then packed into the core of a thousand megawatt reactor within a cylindrical space, fourteen feet high and twenty feet in diameter. Fuel fabrication workers are once again exposed to gamma radiation emanating from the uranium, as well as to radon gas and uranium dust.[23]

Routine Releases from Operation of Nuclear Power Plants

One hundred tons of uranium are placed in the core of a 1,000 megawatt nuclear power plant and immersed in water. When uranium is packed tightly together and the moderating rods made of boron are slowly removed, the uranium reaches critical mass.

Neutrons ejected from the atoms hit other uranium atoms which then break apart, ejecting more neutrons. A by-product of this process is the creation of over 200 new radioactive elements that didn't exist until uranium was fissioned by man.

The resulting uranium fuel is a billion times more radioactive than its original radioactive inventory.[24] A regular 1,000 megawatt nuclear power plant contains an amount of long-lived radiation equivalent to that released by the explosion of 1,000 Hiroshima-sized bombs. This process inevitably entails the release of radioactive materials into the environment. Over time the uranium swells. Pinhole breaks appear in the zirconium cladding, and some faulty welds rupture in the zirconium fuel rods themselves, releasing radioactive isotopes or elements into the cooling water. In addition, radiation emitted through the wall of the fuel rods activates water molecules and creates radioactive elements in the water itself. For example, neutrons emitted from the fuel rods interact with water molecules to form tritium—a radioactive isotope of hydrogen. The primary coolant—water that cools the reactor core—thus becomes intensely radioactive.

This thermally hot primary coolant is piped through a steam generator to heat the secondary cooling system. This secondary water is converted to steam, which turns the generators to produce the electricity. The primary coolant is not supposed to mix with the secondary coolant, but it routinely does, allowing radiation to be released to the environment from this secondary system.

Radioactive gases that leak from fuel rods are also routinely released or "vented" into the atmosphere at every nuclear reactor. These gases are temporarily stored to allow the short-lived isotopes to decay and then released to the atmosphere through engineered holes in the reactor roof and from the steam generators. This process is called "venting." About 100 cubic feet of radioactive gases are also released hourly from the condensers at the reactor. Planned ventings increase in frequency when the reactor shuts down due to mechanical malfunctions. Accidental ventings are not infrequent.[25]

Planned "purges," when radioactive gases are actively flushed into the atmosphere by a fan, are officially permitted by the NRC so that utility operators can decrease the intensely radioactive environment into which maintenance workers must enter. Older reactors are allowed twenty-two purges per year during routine operation and two purges per year during cold shutdown.[26] (Cold shutdown occurs when the fission reaction is stopped at the reactor and 30 tons of very radioactive fuel is removed and replaced by new fuel).

Some of the more dangerous gases, such as iodine 131, are usually trapped by filters, but not always. After the radioactive iodine is filtered, noble gases are routinely released. The nuclear industry argues that noble gases are chemically inert and therefore not capable of reacting biochemically in the body, but they actually decay to daughter isotopes, which themselves are chemically very reactive.

Noble gases have names that bring to mind Superman—xenon, argon, krypton. There are many varieties of these elements, some of which are described below. Noble gases are high-energy gamma emitters, and they are readily absorbed from the lung and enter the blood stream. Although they are chemically non-reactive, they are very fat soluble, and they tend to locate in the abdominal fat pad and upper thighs, adjacent to the testicles and ovaries. There, they can induce significant mutations in the eggs and sperm of the people living adjacent to a reactor.[27]

There have never been any epidemiological studies performed on the effects of exposure to the noble gases xenon and krypton.[28] This is a grave deficit in the study of radiation biology, because these gases are so ubiquitous around nuclear reactors and are released with irresponsible impunity. Several of the more dangerous isotopes to which noble gases decay (all of which have different metabolic pathways in the body) include the following:[29]

- Xenon 137, with a half-life of 3.9 minutes, converts almost immediately to the notoriously dangerous cesium 137 with a half-life of thirty years.
- Krypton 90, half-life of 33 seconds, decays to rubidium 90, half-life of 2.9 minutes, then to the medically toxic strontium 90, half-life of twenty-eight years.
- Xenon 135 decays to cesium 135 with an incredibly long half-life of 3 million years.
- Large amounts of xenon 133 are released at operating reactors, and although it has a relatively short half-life of 5.3 days, it remains radioactive for 106 days.
- Krypton 85, which has a half-life of 10.4 years, is a powerful gamma emitter.
- Argon 39 has a 265-year half-life.

Other dangerous noble gases include xenon 141, 143, and 144, which decay to cerium 141, 143, and 144. According to the National Council on Radiation Protection (NCRP Report No. 60) these three cerium isotopes, which are beta emitters, are abundant products of nuclear fission reactions and have moderately long half-lives. They bio-concentrate in the food chain, and they irradiate the lung, liver, skeleton, and gastrointestinal tract, where they act as potent carcinogens.[30]

A very important and little-discussed isotope that is routinely emitted in large quantities into the air and waste water from nuclear power plants is tritium (H_3), a radioactive isotope of hydrogen, composed of one proton and two neutrons. Tritium has a half-life of 12.4 years and as such is radioactive for 248 years. H_3 combines readily with oxygen to form tritiated water (H_3O).

Because it is impossible to remove tritium gas or tritiated water via filters, tritium is released continuously from reactors into the air and into lakes, rivers, or seas—depending upon the reactor location. At least 1,360 curies of tritium are released annually from each reactor.[31] (A curie is the amount of radiation equal to the disintegration of 37 billion atoms per second.) Tritium gas is an interesting radioactive material, which is utilized extensively in exit signs, runway signs at airports, and on watch faces. It is very reactive and tends to chemically bind with any material in which it is enclosed.

Tritiated water in particular is scary material. If one is immersed in a cloud of tritiated water on a foggy day near a reactor, it is absorbed straight through the skin. It is also readily absorbed through the lungs and the GI tract. Because tritium is a soft energy beta emitter, meaning that it does not penetrate very far, all the radiation it gives off is readily absorbed by the surrounding cells, hence it is biologically very mutagenic.

There is a vast literature on the biological effects of tritium demonstrating that it causes chromosomal breaks and aberrations. In animal experiments, it has been shown to induce a fivefold increase in ovarian tumors in offspring of exposed parents, while also causing testicular atrophy and shrinkage of the ovaries. It causes decreased brain weight in the exposed offspring and mental retardation with an increased incidence of brain tumors in some animals. Increased perinatal mortality was observed in these experiments as well as a high incidence of stunted and deformed fetuses. (These effects were observed with surprisingly low concentrations of tritium.)[32]

Tritium is also more dangerous when it becomes organically bound in molecules of food.[33] As such it is incorporated into molecules, including DNA within bodily cells. Chronic exposure to contaminated food causes 10% of the tritium to become organically bound within the body where it has a biological half-life of 21 to 550 days—meaning that it can reside in the body from one to twenty-five years.[34]

When tritium is released to the environment, it is taken up by plants and trees, partially incorporating into the ecosystem. Trees constantly transpire water vapor into the air; it has been found that higher concentrations of tritium occur at night at breathing height in a forest that has incorporated tritium from a nearby reactor.[35]

Let's look again at the reactor.

As discussed above, the primary coolant water becomes extremely radioactive over time because the fuel rods leak. The NRC is now allowing nuclear operators to retain uranium fuel in reactors for six years instead of three, lengthening the "burnup" time and substantially increasing the radiation levels in the fuel. The NRC is also allowing a concentration of 4.5% uranium enrichment in the fuel instead of the previously approved maximum of 3.5%. This policy will not only substantially increase the amount of radioactivity produced in the fuel rods, but also subject old reactors to increased power production, which could induce damage in pipes and engineering equipment that have become embrittled and fragile after years of intense radiation exposure. Also, the longer the time that the zirconium fuel cladding is exposed to high levels of radiation, and the higher the radiation levels, the greater the damage to the cladding and subsequent leakage of radioactive materials into the primary coolant.

Radioactive corrosion or activation products that are not the result of uranium fission are also produced, as neutrons bombard the metal piping and the reactor containment. These elements, which are powerfully radioactive, include cobalt 60, iron 55, nickel 63, radioactive manganese, niobium, zinc, and chromium. These materials slough off from the pipes into the primary coolant. Officially called CRUD, it is so intensely radioactive that it poses a severe hazard to maintenance workers and inspectors in certain areas of the reactor.[36]

According to David Lochbaum, a nuclear engineer at the Union of Concerned Scientists, during shutdowns of reactors, the utilities not uncommonly flush out pipes, heat exchangers, etc., to remove highly radioactive CRUD build-up. Some of the CRUD is sent to radioactive waste dumps while some is released to the river, lake, or sea nearest the reactor.[37]

Although the nuclear industry claims it is "emission" free, in fact it is collectively releasing millions of curies annually. Reports documenting gaseous and liquid radioactive releases vary enormously depending upon accidental and larger-than-normal routine releases. The Millstone One reactor in Connecticut alone released a remarkable 2.97 million curies of noble gases in 1975, whereas Nine Mile Point One released 1.3 million curies in 1975. In 1974, the total release from all reactors in the United States was 6.48 million curies, and in 1993 it ranged between 96,600 curies to 214,000 curies.[38] Releases vary according to equipment failure, which is variable and fickle. By contrast, coal plants release some uranium and uranium daughter products in their smoke but very little radiation compared to atomic plants, and certainly no fission products.

The utilities also admit that about 12 gallons of intensely radioactive primary coolant leaks daily into the secondary coolant via the steam generator through breaks in the pipes. Some of these emissions, which occur when the steam is released to the air, are not even monitored.[39] Likewise, about 4,000 gallons of primary coolant water are intentionally released to the environment on a daily basis, while some just leaks out unplanned. Many other emissions are simply not monitored.[40]

Very radioactive primary coolant filters, which often contain intensely carcinogenic plutonium 238, 239, 241, americium, and curium, are shipped to nuclear waste facilities where they will inevitably leak and contaminate water supplies and food chains. But other dangerous elements in the filters are almost certainly present in the primary coolant and escaping in small quantities via the gaseous or liquid effluents into the environment, including: technetium 99 with a 211,100-year half-life, iodine 129 with 15,700,000-year half-life, carbon 14 with a 5,700-year half-life, nickel with a 100.1-year half-life, and plutonium 241 with a

14.29-year half-life. Once in the environment, these carcinogens will bio-concentrate in the food chain, there to enter human bodies![41]

It is important to note that most of the data on radiation releases are not real measurements but are only estimates made by computerized mathematical models based on data generated from operational reactors, field and laboratory tests, and plant-specific design calculations. Hence the nuclear industry is consistently guessing about its radioactive releases and has no real idea what specific isotopes are escaping from its plants. The last document available for public scrutiny that quantified actual releases, not just guesstimates, of radioactive materials from nuclear plants was published by the NRC in 1978. (This was published when reactors were relatively young and plagued with fewer corrosion and maintenance problems.)[42]

RADIOACTIVE WASTE

Quite apart from these routine radioactive releases is the almighty problem of radioactive waste. Each regular 1,000 megawatt nuclear power plant generates 30 tons of extremely potent radioactive waste annually. And even though nuclear power has been operational for nearly fifty years, the nuclear industry has yet to determine how safely to dispose of this deadly material, which remains radioactive for tens of thousands of years. Most nuclear waste is confined in huge cooling pools, euphemistically called "swimming pools" at reactor sites, or in dry storage casks beside the reactor. But there are many other locations in the United States and other countries where huge quantities of reprocessed toxic material and other radioactive waste from nuclear power plants are left unconfined, leaching, leaking, and seeping through soils into aquifers, rivers, lakes, and seas, where it enters and concentrates in the food chains of plants, fish, animals, and humans.[43]

We will now examine several of the precise radioactive materials that the nuclear fission process creates, with their specific health implications for human beings. For simplicity's sake we will consider the properties and medical dangers of only four of these 200 isotopes, giving examples of contamination that has already occurred as they have leaked from their respective reactors.

Plutonium

A typical alpha emitter is plutonium, named after Pluto, the Greek god of hell. Said by its discoverer, Glen Seaborg, to be the most dangerous substance on earth, it is so toxic and carcinogenic that less than one-millionth of a gram if inhaled will cause lung cancer. It is translocated from the lung by white blood cells and deposited in the lymph glands in the middle of the chest where it can mutate a regulatory gene in a white blood cell or lymphocyte causing lymphoma or leukemia. From there it can be solubilized, and, because plutonium resembles iron, it is combined with the iron transporting protein, transferrin, and taken to the bone marrow to be incorporated into the hemoglobin molecule in the red blood cells. Here the alpha particle irradiates bone cells to cause bone cancer and white blood cells made in the bone marrow to cause leukemia. It is stored in the liver where it causes liver cancer, and it is teratogenic, crossing the placenta into the developing embryo.

Plutonium is also stored in the testicle adjacent to the precursor cells, spermatocytes, that form the sperm. Here it will cause mutations in the reproductive genes and increase the incidence of genetic disease in future generations. It also causes testicular cancer. Every male in the Northern Hemisphere has a tiny amount of plutonium in his testicles from radioactive fallout that is still falling on the earth from the upper atmosphere, which was polluted by the atmospheric weapons tests conducted by the United States, the Soviet Union, China, France, and Britain in the 1950s and 1960s.

The half-life of plutonium 239 is 24,400 years, so it remains radioactive for half a million years. Therefore, plutonium lives on to enter and damage reproductive organs for the rest of time, and the genetic mutations it causes are passed on successively to future generations for thousands of years. To give an indication of the length of time involved, it takes up to twenty generations for recessive mutations to come together to express themselves as a specific disease entity, such as cystic fibrosis.

Plutonium is so carcinogenic that the half ton of plutonium released from the Chernobyl meltdown is theoretically enough to kill everyone on earth with lung cancer 1,100 times if it were to be uniformly distributed into the lung of every human being.[44]

Though only 10 pounds of plutonium—a lump the size of a grapefruit—will make an effective atomic bomb, literally hundreds of tons of plutonium are lying around the world, some of it relatively unguarded. The design for an atomic bomb can easily be found on the Internet; some basic materials purchased at the local hardware shop will complete production. The fact that plutonium is a by-product of nuclear power explains why any country that owns a nuclear power plant has access to atomic bomb fuel. Therefore, nuclear power is integral to the ever-growing problem of nuclear proliferation.

However, the United States has historically maintained a strict separation between civilian nuclear power plants and military reactors that produce plutonium for bombs, although they are similar machines. Recently, however, that clear line of separation has been breached, because tritium, which is an integral part of a nuclear weapon, is now being manufactured at the Watts Barr nuclear power plant in Tennessee.

Iodine 131

Radioactive iodine 131, with a half-life of eight days, is a very volatile isotope, meaning that it is usually released from nuclear reactors as a gas, either from routine or accidental emissions. It is both a beta and a high-energy gamma emitter, and as such it is very carcinogenic. When humans and animals are exposed to this pollutant in the air, they inhale it into their lungs, where it is absorbed through the lining of the alveoli or air sacs and enters the blood stream. Iodine 131 also deposits onto the soil near nuclear reactors, where it is taken up by grass and the leaves of plants and concentrated by orders of magnitude in grass and vegetables.

When cattle eat this radioactive grass, iodine 131 is concentrated again in their milk. Radioactive iodine enters the human body in one of two ways—either via the gut when dairy products from cows eating this grass are consumed or via the lung when radioactive gases are released routinely or accidently into the air from the reactor. Iodine 131 circulates in the human blood stream and is avidly absorbed by the thyroid gland at the base of the neck. Children are at special risk from this isotope because their tiny thyroids avidly absorb iodine from the blood like a sponge.

Strontium 90

Strontium 90 is an isotope released from reactors in small amounts on a daily basis, mostly in the waste water but sometimes in air. It is often released in larger quantities when accidents occur at nuclear power plants. It is a beta and gamma emitter with a half-life of twenty-eight years—radioactively dangerous for 600 years. As a calcium analogue, strontium 90 mimics calcium in the body. After release from a nuclear power plant, it lands on the soil, where it is taken up and concentrated by orders of magnitude in grass, concentrated further in cow and goat milk and in the breasts of lactating women, where it can induce breast cancer many years later. Babies who drink this contaminated human breast milk or cows' milk will be exposed to strontium 90, which enters the gut, is absorbed and carried in the blood stream, and laid down in teeth and bones, there to induce bone cancer or leukemia years later.

Cesium 137

Cesium 137 is an isotope with a half-life of thirty years, radioactive for 600 years. As a potassium analogue, it is present in every cell of the body. Cesium 137 tends to concentrate in animal muscle and fish, and it deposits in human muscles where it irradiates muscle cells and other nearby organs. It is a dangerous beta and high-energy gamma emitter and is very carcinogenic. An old, dirty reactor at Brookhaven National Labs in the middle of Long Island in the 1970s and 1980s released large amounts of radiation for many years,[45] and an epidemic of a very rare form of cancer called rhabdomyosarcoma appeared in children living near that reactor in the 1980s. This very malignant muscle cancer could be caused by exposure to cesium 137.[45a]

Dr. John Gofman, the discoverer of uranium 233, estimates that if 400 reactors operated for twenty-five years at 99.9% perfect cesium containment, cesium loss over this period would be equivalent to sixteen Chernobyl accidents.[46]

NUCLEAR ACCIDENTS

Abnormal releases of small or large quantities of radiation at nuclear power plants occur not infrequently and are referred to by the nuclear industry as “incidents.” These “incidents” occur because of human or mechanical error or because the operator at the reactor has purposefully decided to vent radioactive gases to get rid of them.

Several incidents have had catastrophic ramifications. A meltdown occurred at the Three Mile Island reactor in the United States and a massive power excursion erupted at the Chernobyl nuclear power plant in Russia. These were both induced by human error and fallibility. Because the reactors around the world are aging and suffering from cumulative metal fatigue induced by high radiation exposure, there is a high probability that another meltdown will occur in the near future.

There have been several near-misses at large nuclear power plants in the United States over the years. One took place at the Browns Ferry reactor in Alabama in 1975, when two electricians using candles to check for air leaks accidentally ignited highly combustible polyurethane foam that was used as sealant. The fire rapidly spread to plastic cables that surrounded other cables that controlled the operation of the reactor and emergency core cooling system. The fire raged in the bowels of the plant for seven-and-a-half hours, severing thousands of cables and debilitating most of the control systems and the emergency core cooling system. The water level in the reactor core dropped sharply and was restored only when workers resorted to equipment that was not designed for emergency cooling systems.[47] A more recent "near-miss" occurred at the Davis-Besse plant in December 2001; this accident is described in the next chapter.

Three Mile Island

Before Three Mile Island melted down, the nuclear industry used to say that the chance of a meltdown occurring was the same as that of a person being hit by a bolt of lightning in a parking lot.

Beginning at 4 A.M. on March 28, 1979, lightning struck. A meltdown at the Three Mile Island nuclear power plant in Pennsylvania was triggered when a mechanical failure and an automatic shutdown of the main feedwater pumps in the secondary coolant system closed some valves, causing water in the primary coolant system covering the radioactive core to overheat. This quickly cascaded into a series of automated events and human misinterpretations, which caused the reactor core of 100 tons of uranium to overheat and to melt. Throughout the accident, highly radioactive cooling water was being pumped through a valve onto the floor of the reactor and thence into a tank in an adjacent auxiliary building where large quantities of radioactive gases were vented from a leaking valve into the external atmosphere.

Warm weather at the time of the leak compounded the crisis, with low winds and a cold upper air mass preventing the warm air from rising, producing ideal conditions for trapping the radioactive emissions.[48]

We know for a fact that large amounts of radioactivity escaped from the Three Mile Island accident. But, the nuclear industry and the government did not collect release estimates for specific isotopes,[49] and to this day, there is no available information about which specific isotopes escaped nor the actual quantity of radiation that was released.[50] The gamma radiation monitor on the auxiliary building where all the radiation was released was not designed to measure such high concentrations of radiation, so it went off scale very early in the accident, an emergency which continued over several days. Thus, the only estimates of radiation release were made by extrapolating data obtained from gamma radiation monitors—thermoluscent dosimeters (TLDs)—which were located hundreds of feet from the stack low down on the fence line that surrounded the reactor. Of the twenty TLDs (that only measure gamma radiation, not beta, which was three to five times the gamma dose), only two were anywhere near the "hot" passing cloud, hence it is impossible to judge the dose to thousands of people from only two readings.[51] Most of the radioactive plumes would have been lofted into the air well above these monitors, so only small increments of radiation in the gaseous plumes could possibly have been measured. Measurements of noble gas were not commenced until April 5, some eight days after the meltdown first began. No alpha or beta radiation was ever measured. It is known that radioactive emissions from Three Mile Island travelled long distances. For instance, xenon 133 was measured in Albany, New York, at the end of March and early April 1979, 375 kilometers from the reactor.[52]

Radiation releases and dose estimates were therefore determined using extremely inadequate data. The nuclear industry estimated that 13 to 17 curies (1 curie is the amount of radiation equal to the disintegration of 37 billion alpha or beta particles per second) of radioactive iodine escaped, plus 2.4 to 13 million curies of the noble gases krypton, xenon, and argon.[53] But, as the former chairman of the Nuclear Regulatory Commission (NRC), a government-appointed body that oversees the regulation of nuclear power, Joseph Hendrie was quoted at the time as saying, "We are operating almost totally in the blind, [Governor Thornburgh's] information is ambiguous, mine is nonexistent and—I don't know—it's like a couple of blind men staggering around making decisions."[54]

However, based on measurements of radioactive iodine in animals nearby, experts felt the nuclear industry's estimates were grossly understated. Also the March 24, 1982 notes of Dr. Karl Morgan, estimated that 45 million curies of noble gases were released and 64,000 curies of radioactive iodine were released and that the thyroid dose to the population was at least 100 times that of the NRC estimate.[55] Dr. Morgan was a highly respected health physicist known as the "Father of health physics."

Dr. Carl Johnson M.D., M.P.H., an expert in radiation related diseases, estimated that because the fuel melted, many other elements almost certainly escaped from the reactor core, including plutonium, strontium, and americium. When he asked the NRC and the DOE to do a survey to look for these elements in the respirable dust around Three Mile Island after the accident, they refused.[56]

It is known that on day three of the accident, 172,000 cubic feet of high-level radioactive water were released into the Susquehanna River by the utility without NRC permission, an event unheard of in the history of the nuclear industry. The Susquehanna River drains into Chesapeake Bay, a major fishing location.[57] This water contained high concentrations of many dangerous, long-lived isotopes, which would then have been avidly bio-concentrated by fish, lobsters, and crabs over a period of weeks, months, and years. The public, however, was not notified about this danger, as they were not notified about many aspects of this accident.

Large quantities of radioactive krypton 85 were purposefully vented from the damaged reactor in June 1980, exposing even more people to radioactive contamination.[58] And in November 1990, 2.3 million gallons of radioactive water containing tritium was also purposefully evaporated from the damaged reactor building, exposing many people in the vicinity to dangerous radioactive elements.[59]

During the first two days of the accident, pandemonium ensued as 5% to 6% of the people who lived within five miles of the plant fled. On March 30, two days after the accident, Governor Thornburgh ordered the evacuation of pregnant women and children from the five-mile zone.[60] One hundred and forty-four thousand people packed up and fled, jamming the highways, with babies bundled in blankets, children with scarves wrapped across their faces to limit their exposure to radiation, and pregnant women in sheer panic.[61] I was in Harrisburg, Pennsylvania, a week after the accident to explain the effects of radiation to thousands of frightened residents in the gymnasium of the high school when it was reported to me that local physicians fled with their families, leaving their patients in the hospitals to fend for themselves.

Hundreds of local people reported a variety of symptoms and signs that were similar to the symptoms reported almost a decade later by residents of Pripet, the town adjacent to Chernobyl where another nuclear meltdown occurred and the release of radiation was much greater than that at Three Mile Island.[62] These symptoms included nausea, vomiting, diarrhea, bleeding from the nose, a metallic taste in the mouth, hair loss, and a red skin rash. These are the typical signs and symptoms of acute radiation sickness, which manifest when people are exposed to whole-body doses of radiation around 100 rads—a high level of exposure. This dose kills the actively dividing cells of the body—hair, gut, and blood—a situation that induces these symptoms. The people near Three Mile Island also reported deaths of farm animals and pets.[63]

Dr. Gordon McLeod, Pennsylvania health commissioner at the time of the accident, noted that the number of babies born with hypothyroidism increased from nine in the nine months prior to the accident to twenty in the nine months following the accident, and he postulated that this was because the thyroid gland was affected by the large quantities of iodine 131 that escaped during the accident. Dr. McLeod's finding indicates that some people who were exposed to iodine 131 as babies and children may well be developing thyroid cancer as they are in the exposed population from Chernobyl, but if nobody investigates the situation epidemiologically these patients will not be identified. McLeod was fired by Governor Richard Thornburgh just six months after he took office.[64]

A Food and Drug Administration document dated April 6, 1979, analyzed milk collected on April 4, 1979 from many farms in the area surrounding the Three Mile Island reactor. Fifteen of the samples showed elevated levels of iodine 131 and twelve showed elevated levels of cesium 137.[65] The farms were located at all four sectors of the compass, meaning the radioactive plume moved 360 degrees from the day of the accident to seven days thereafter. It's also interesting that the farms whose milk tested positive were varying distances from the reactor—from 150 miles north to 9 miles south, 15 miles west to 13 miles east. Hershey Chocolate factory is located 13 miles from Three Mile Island in the richest dairying area of the United States. At the time of the accident most of Hershey's milk supply came from Pennsylvania.

A memo written on April 11 to W.J. Crook, of Hershey's Science and Technology Department by C.J. Crowell, the Quality Assurance Manager of Hershey's, in response to a discussion between the two men the previous day is significant. One statement in this document said that they continued to check the liquid milk inside the five mile zone adjacent to the plant and that "no detectable radiation has been found since a few days after the accident," which appears inconsistent with the information in the previously mentioned FDA report where radiation was found in the milk up to one week post accident many miles outside the five mile zone.[66]

However a confidential memo from Hershey states that between the dates of April 2 to April 20, 12,270,000 pounds of milk were powdered, instead of 6,095,000 pounds that would normally have been converted to powder during that time. When milk is powdered it is preserved in a usable form until the radioactive iodine decays. However this technique does not obviate cesium 137 in the milk, which lasts 600 years, nor other long-lived radio-isotopes should they also be present in the contaminated milk. Hershey was obviously concerned about their milk supply; however, they repeated in this document that no detectable radiation was found in this milk "since a few days after the accident."

But another study also performed on milk on March 30, 1979 by the Pennsylvania State University, College of Engineering, which was sent by K.K.S. Pillay to Dr. Carl. Y. Wong, Group Leader of Product Research at Hershey Foods Corporation, found 3,000 picocuries/liter in milk from farms located 12 and 15 miles from the reactor, 3,500 picocuries/liter from a farm 7 miles away, 4,000 picocuries/liter from another farm 16 miles away, and three calculations from unidentified farms measuring 6,000 picocuries/liter, 8,500 picocuries/liter to 21,500 picocuries/liter.[67] Some of these levels are very high. If a one-year-old child drank a liter of milk containing 21,300 picocuries/liter, she would receive a dose of about 0.3 rems to her thyroid, which could result in thyroid cancer years later. If she consumed more than one liter of contaminated milk the dose would increase accordingly.

However a quote from Thomas Gerusky, the director of Radiological Health from the Pennsylvania Department of Environmental

Resources (DER) in the April 8 edition of the *Harrisburg Sunday Patriot News* said that, "If we ever found a thousand picocuries we would take action." These measurements from Pennsylvania State University indicate that action should have been taken.[68]

The question is, was the DER informed about the high levels of radiation in the milk, or were they hidden? If on the other hand the DER was informed, why did they do nothing?

The cows were out at pasture on the day of the accident because it was early spring, but on March 29 they were removed from the fields and fed on silage, which would not have been contaminated. The cows were therefore not subject to excessive radiation absorption through their GI tracts. Therefore radiation must have entered through their lungs, absorbed from highly contaminated air.

If the cows were contaminated, so too were humans. Why then were the cows tested for contamination but not people?

This question remains pertinent twenty-six years post meltdown. If radioiodine and cesium 137 escaped, so too did various quantities of strontium 90, plutonium, americium, and other extremely dangerous and long-lived materials. What are the ground measurements of these elements on the land where the cows graze that produce milk for Hershey's chocolates, if indeed they were ever taken or analyzed? Why has this data never been released?

Subsequently and strangely, there has been a deficit of studies performed on the medical outcomes of this accident and a plethora of studies relating people's symptoms to stress. Two medical papers emerged from Columbia University investigators, which reported a positive association between radiation exposures and increased incidences of non-Hodgkin's lymphoma, lung cancer, all other cancers combined, plus childhood leukemia. However, these findings were statistically insignificant because of the small overall numbers of cases (fifty-four), and the team used estimated radiation exposures performed by the government and nuclear industry, which were artificially small. The Columbia team decided that their findings were unrelated to radiation exposure because the doses had been too low to initiate the increase in the malignant diseases that they found. They also postulated that increased cancer rates were caused by stress![69]

However, another study later performed by Steve Wing and others found positive relationships between accident dose estimates and the increased incidence of cancer that was reported by the Columbia group.[70] They used the same dose estimates as did the Columbia team, but they did not make the same assumption that the absolute radiation level to which the public was exposed was below the background levels of radiation.

The official health studies were paid for by the TMI Public Health Fund, which was set up by the nuclear industry and funded by industry payments, which also settled property damage suits. At no stage did the nuclear industry confer with or obtain evidence from citizens who believed that they had been impacted by the accident.[71] These people were excluded when the questions were formulated; they were excluded from participation in the study design, interpretation, and analyses; and they were not told of the results. To add insult to injury, those people who dared to testify about their experiences and physical symptoms were often subjected to ridicule at hearings.[72]

The Three Mile Island case eventually ended up in court, when approximately 2,000 residents claimed that the radioactive releases from the meltdown had been much larger than those officially proclaimed by the nuclear industry and government officials. After several dismissals and appeals, however, the plaintiffs decided that they could no longer afford to continue and had to settle.[73]

Dr. Wing, a famed epidemiologist who represented the plaintiffs, noted for the record his impression that the industry's image and liability were more important than the accuracy of data and full disclosure. Wing pointed out that, historically, disputes between industry, governments, and community are always unequal and unfair because people who have been damaged by irresponsible industries almost never have the expertise or funding to conduct their own studies.[74]

Surprisingly, the cancer incidence in the exposed population was studied only through the years 1981–1985, several short years post-accident.[75] There have been virtually no further epidemiological studies performed since that time, even though the latent period of carcinogenesis is two to sixty years and even though the long-lived isotopes strontium 90, cesium 137, and others almost certainly escaped during the accident.

It is imperative that further studies be implemented on the exposed Three Mile Island population. In a relevant precedent, for many years scientists insisted that the fallout from the U.S. aboveground nuclear weapons testing during the 1950s and 1960s had produced no health impacts. In 1997, when studies were finally performed, the National Cancer Institute (NCI) estimated that as many as 212,000 Americans had developed or would develop thyroid cancer from the radioactive iodine released from the tests.[76] And even then this study was inadequate because the NCI did not estimate different types of cancer that would have been induced by the many other radioactive elements such as strontium 90, cesium 137, and plutonium that were released from these aboveground nuclear tests.

In 1991, Dr. Karl Morgan, the founder of the discipline of health physics, looking retrospectively at the track record of that field, wrote that health physics was intended "to be a science and profession to protect radiation workers and members of the public from exposure to ionizing radiation. It succeeded to some extent in this objective but during the past decade in the United States, it has reverted to an organization primarily to protect the nuclear industry from liability resulting from radiation exposure."[77]

There were two reactors at Three Mile Island. One is still in operation generating electricity. The melted core of the damaged reactor has been dismantled. It took some eleven years to clean up the melted and fragmented fuel rods, which were intensely thermally and radioactively hot. Ninety-nine percent of this material was sent by truck to the Hanford reservation in Washington State and to the Idaho National Engineering Labs in Idaho Falls. The reactor building itself remains intensely radioactive, significantly more so than a reactor building at the end of its forty years of operation.[78]

A lawsuit initiated in 1992 by Eric Epstein against General Public Utilities, then owner of Three Mile Island, resulted in the establishment of a state-of-the-art monitoring system around Three Mile Island. Gamma monitoring equipment, which itself is continuously monitored, has been deployed in sixteen locations within three miles of Three Mile Island. During the years 2003–2005, this monitoring system was enhanced by the addition of five state-of-the-art radiation monitors, which feed information into the central control system at Penn State University.[79] No further cancer studies have been implemented in the exposed population, although a 2002 report issued by the National Cancer Institute and the Centers for Disease Control and Prevention found that Pennsylvania had the seventh-highest cancer incidence in the nation.[80]

In February 1985, however, $3.9 million dollars were paid out in settlements to people who had developed diseases related or unrelated to radiation by the insurance company representing General Public Utilities Corp. and Metropolitan Edison Co., the owners of Three Mile Island. The claimants were told there could be no further claims by them for liability and in exchange for the compensations paid they agreed not to discuss the settlements.[81]

Chernobyl

Before the Chernobyl meltdown, the nuclear industry assumed that, in the event of an accident at a nuclear power plant, only a tiny percentage of the radioactive inventory of the reactor core would escape from the containment into the environment. On April 26, 1986, when Unit Four of the Chernobyl nuclear power plant exploded, however, almost all the contents of the deadly radioactive fission products were spewed into the environment.[82] This medical catastrophe will continue to plague much of Russia, Belarus, the Ukraine, and Europe for the rest of time.

However, in 2005, the International Atomic Energy Agency (IAEA) produced a United Nations report on Chernobyl, claiming that only fifty-six people had died as a result of the accident. The IAEA has a conflict of interest when it comes to monitoring the health consequences of radiation because, in 1959, the IAEA signed a somewhat diabolical agreement with the World Health Organization (WHO), preventing WHO from researching health consequences emanating from atomic, military, and civilian use of the atom, even preventing them from issuing warnings to exposed populations. Dr. Michael Fernex, formerly on the faculty of the University of Basel, who worked with the WHO, said in 2004, "Six years ago we tried to have a conference. The proceedings were never published. This is because in this matter the organizations at the UN are subordinate to the IAEA. . . . Since 1986, the WHO did nothing about studying Chernobyl. It is a pity. The interdiction to publish which fell upon the WHO conference came from the IAEA. The IAEA blocked the proceedings; the truth would have been a disaster for the nuclear industry."[83]

So in order to prevent a disaster befalling the nuclear industry, the magnitude of the *true* disaster is deliberately being obfuscated.

These are some of the medical and ecological consequences of Chernobyl that we know today:

- Of the 650,000 people called "liquidators" involved in the immediate cleanup, 5,000 to 10,000 of them are known to have died prematurely.[84]

- Large areas of the breadbaskets of the Ukraine and Byelo-Russia became heavily contaminated and will remain so for thousands of years. In all, 20% of the land area of Belarus, 8% of the Ukraine, and 0.5% to 1% of Russia—100,000 square miles—were contaminated. In total, this area is equivalent to the state of Kentucky or of Scotland and Ireland combined. Five million people live in these areas, over 1 million of whom are children, who are inordinately sensitive to radiation. The incidence of cancer among this population has increased. Many of the genetic abnormalities and diseases caused by this accident are generations away and will not be seen by anyone alive today.
- Heavy radioactive fallout occurred over Austria, Bulgaria, Czechoslovakia, Finland, France, East and West Germany, Hungary, Italy, Norway, Poland, Romania, Sweden, Switzerland, Turkey, Britain, the Baltic States, and Yugoslavia. Small amounts also landed on Canada, the United States, and all other countries in the Northern Hemisphere.[85] Because cesium 137 and other isotopes such as strontium 90 and plutonium 239 have such long half-lives, some of the food in Europe will be radioactive for hundreds of years, depending upon the hot spots that were contaminated when the radiation fell to the earth as rain.
- In Britain, twenty-eight years post-accident and 1,500 miles from the crippled reactor, 382 farms containing 226,500 sheep are severely restricted because the levels of cesium 137 in the meat are too high. Before the sheep are sold for meat, they must be transferred to other less radioactive grazing sites so that their levels of cesium decrease before sale.[86] Meanwhile, people in Britain are still eating low levels of cesium in their meat.
- In the south of Germany, very high levels of cesium in the soil persist; hunters are compensated for catching contaminated animals, and many mushrooms and wild berries are still too radioactive to eat.[87]

- The French government initially insisted that the radioactive fallout stopped exactly at the French border. Recent documents reveal, however, that the government knew that radioactivity in France surpassed all safety levels at the time of the accident.[88] Other European countries ruled that fresh vegetables and dairy products could not be sold for several months and that children were not to play outside for a similar short time span, but the French government denied that France was affected. Only now do they admit that cesium 137 in some parts of France is as high as some extremely contaminated areas in Belarus, the Ukraine, and Russia. A country that loves its food, mushrooms, and wild boar shows very high levels of contamination, mainly in the form of cesium 137.[89] Perhaps the fact that France has fifty-eight nuclear reactors and derives 80% of its electricity from nuclear power is related to the government's cover-up.[90]

The reindeer as far away as Scandinavia were contaminated with cesium after the Chernobyl meltdown, because the lichen in the Arctic Circle avidly concentrated the cesium as it landed on them from the fallout. (I visited Sweden just after the accident and stupidly ate some reindeer meat!) Signs in Bavarian forests warn people not to eat the mushrooms—this is because they are very efficient concentrators of radiation, particularly cesium 137.

In all my years of pediatric practice, I have never seen a child with thyroid cancer, because childhood incidence is so extremely rare. Yet in Belarus near Chernobyl from 1986 to 2001, 8,358 cases of thyroid cancer occurred, 716 in children, 342 in adolescents, and 7,300 in adults.[91] The situation post-Chernobyl is a medical emergency, unique in the history of pediatrics. Most of those affected have had their thyroids surgically removed, but a person cannot survive without the hormones produced by the thyroid gland, so these children and adults are dependent upon receiving thyroid replacement tablets every day for the rest of their lives. Should some catastrophic situation such as a war impede their drug supply, they will die.

Chernobyl also impacted the daily lives of 400,000 people who resided in the most contaminated areas of the Ukraine, Belarus, and Russia. Because of the accident, they were forced to leave their homes, their past, their friends and their communities forever. Many were relocated to other areas (often to find that the land was just as radioactive as the homes and gardens that they vacated). They now live with the fact that they and their children are forever contaminated and could develop cancer or produce a new generation of children with severe birth defects.[92]

Although the food in many parts of Europe is still relatively radioactive as evidenced in the data presented in this chapter, this terrible problem is rarely mentioned in the media or in daily conversation. In a form of psychic numbing, people continue to live their lives as if all were well, and the nuclear power industry continues to broadcast the myth that its product is clean and green.

In 1994, the United Nations Office for the Coordination of Human Affairs made a tragic statement of remembrance, almost like statements made to memorialize wars:

> Eighteen years ago today, nearly 8.4 million people in Belarus, Ukraine and Russia were exposed to radiation. Some 150,000 square kilometres, an area half the size of Italy, were contaminated. Agricultural areas covering nearly 52,000 sq km, which is more than the size of Denmark, were ruined. Nearly 400,000 people were resettled but millions continue to live in an environment where continued residual exposure created a range of adverse effects.
>
> Now, roughly 6 million people live in affected areas. Economies in the region have stagnated, with the three countries directly affected spending billions of dollars to cope with the lingering effects of the Chernobyl disaster.

> Chronic health problems, especially among children, are rampant.[93]

Eighteen years after the accident, 70% to 90% of the cesium 137, 40% to 60% of the strontium, and up to 95% of the plutonium and its alpha-emitting relatives remain in the upper root–inhabiting layers of the soil in Belarus, Ukraine, Russia, and parts of Europe.

In 2001, the United Nations Development Program-United Nations Children's Fund (UNDP-UNICEF) mission summarized:

> The health and wellbeing of populations in the affected regions is generally very depressed. . . . Life expectancy for men in Belarus, Russia and Ukraine, for example, is some ten years less than in Sri Lanka, which is one of the twenty poorest countries in the world and is in the middle of a long drawn out war. . . . Cardiovascular disease and trauma (accidents and poisonings) are the two most common causes of death followed by cancer (this situation is not confined to the Chernobyl affected regions). . . . The health situation encountered in the populations living in the affected territories is thus a complex product of inputs ranging from radiation induced disease, through endemic disease, poverty, poor living conditions, primitive medical services, poor diet, and the psychological consequences of living with a situation that was frightening, poorly understood, and over which there seemed little control.[94]

Thus, the extreme degree of dislocation, fear, and anxiety precipitated by the nuclear disaster also aggravates and potentiates other diseases.

A recent study from Sweden showed an increase of 849 cancers up to the year 1996 as a result of Chernobyl.[95] This is the first study outside Russia, Ukraine, and Belarus to show an effect. It will be the first of many, because the time frame of ten years is relatively short for the incubation of cancer and because other countries have yet to study their affected populations. There are now claims surfacing in France that people are suffering from thyroid cancer that may be related to the Chernobyl fallout.[96]

To put a final terrifying coda to this story, the Chernobyl reactor's radioactive sarcophagus, which was hastily constructed to cover some 20 tons of melted fuel and radioactive dust at the site of the damaged reactor, is disintegrating and cracking and is not expected to remain intact for many more years.[97] If it collapses, it will release huge quantities of radiation that will again be swept across the Ukraine, Belarus, Russia, and parts of Europe, depending upon the wind direction.

The accident is not over.