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Anti-Nuclear Hoaxsters Hide Benefits of Radiation

Fear of radiation has been fostered by unscientific policies and the mass media, reports Dr. Zbigniew Jaworowski. Not only is the danger grossly exaggerated; radiation can be highly beneficial!

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Abstract

Administrative acceptance of the linear, no-threshold dose/effect relationship (LNT) for radiological protection was convenient for regulatory bodies, but is impractical, and inconsistent with observations on beneficial effects of low doses and dose rates of radiation, with a lack of increased malignancy and hereditary disorders in inhabitants of areas with high natural radiation background, and with a lack of genetic effects in progeny of Hiroshima and Nagasaki survivors. Man-made contribution to the average global individual radiation dose from all commercial nuclear power plants, nuclear explosions, and the Chernobyl accident, amounts now to about 0.4%, and from medical x-ray diagnostics 20% of the average natural dose of 2.2 millisieverts (mSv) per year. The natural dose is in many regions of the world two orders of magnitude higher than the current exceedingly low dose limit for population of 1 mSv per year.

Introduction

A prompt criticality accident occurred in September last year at a nuclear plant in Tokaimura, Japan. Three workers absorbed potentially lethal radiation doses of about 4,500 to more than 20,000 mSv. One of them died on the 83rd day after the accident; the other was discharged from the hospital on the 82nd day, and the third, with skin lesions, is being successfully treated by skin grafts (Sasaki, 2000). Radionuclides produced in this accident by the short-term fission reaction, entered the atmosphere, but no significant ground contamination was found outside the plant boundary. Notwithstanding, the local authorities evacuated 150 residents and urged another 310,000 to stay indoors (IAEA-ERC, 1999; Lewis, 1999).

Compared with other industrial accidents occurring every day over the world, and which result in about 12,000 deaths per year in the United States alone, the Tokaimura incident does not seem to have been very serious. Nevertheless, it was described by the media and by International Atomic Energy Agency (IAEA) officials as "the world's third worst nuclear accident behind Chernobyl and Three Mile Island," and the worst nuclear accident in Japan—all of which is indeed correct.

In Japan, nuclear power has been in operation since 1965. Today, 35 years later, almost 36% of its electric power is produced by 53 nuclear reactors. One fatal victim during so long a time just proves the excellent safety of the vast nuclear

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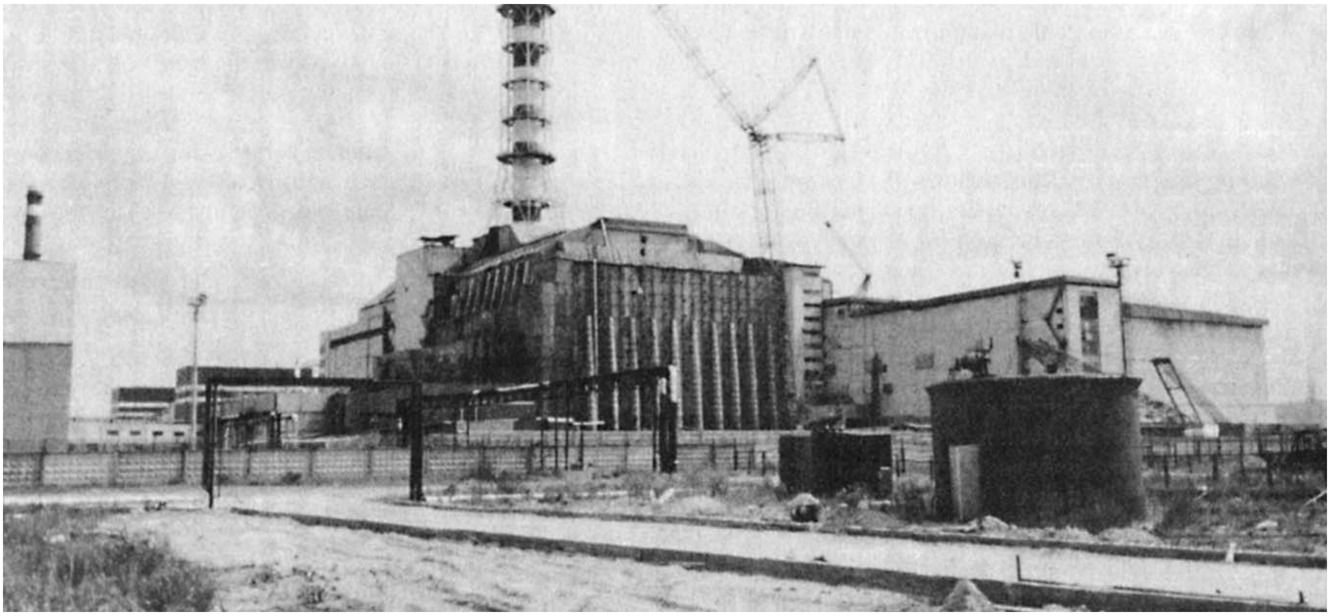


"The man-made contribution to the average global individual radiation dose from all commercial nuclear power plants, nuclear explosions, and the Chernobyl accident, amounts to about 0.4%, and from medical x-ray diagnostics 20%, of the average natural dose of 2.2 mSv per year." Here, the damaged Chernobyl nuclear plant in 1992.

industry in Japan. Every year during the last decade, due to fatal accidents at work, Poland suffered the loss of anywhere between 20 and 110 miners, to produce about half of Japan's electric power output, almost exclusively by burning coal.

Why then did the Tokaimura incident evoke such enormous media outcry? Why did it provoke such a vehement reaction from the public and from local and international authorities? Why did, for several days, the Emergency Response Center of the IAEA in Vienna give reports on the accident, sometimes five times daily, to all Permanent (national) Missions to the IAEA, and to 213 National (emergency) Contact Points all over the world? Why did President Clinton order a safety survey of all American nuclear facilities, as if what had occurred in Japan could somehow extend to the United States?

Nothing like this occurs in any other industry, when three workers get electrocuted, or burned by hot fumes, or die when a cloud of ammonia escapes from a factory or a railway tank. Any minor leak of radioactivity from a broken tube in a reactor, even if completely innocent and bearing no relevance to the overall safety of the plant, is trumpeted throughout the world, and is used to direct mass emotions against the inherently safe and environmentally friendly nuclear energy. What makes people demand that the nuclear industry be a zero accident enterprise? Yet, at the same time, the same people appear to willingly accept all other kinds of man-made accidents, including some 17 million deaths estimated to have been caused by cars since their invention. What causes this paranoiac imbalance? An attempt to answer these questions, is the subject of this presentation.

The Chernobyl catastrophe resulted in vast quantities of radionuclides being released into the global atmosphere, which were easy to measure even high in the stratosphere, and far away at the South Pole (Jaworowski et al., 1997). It was a godsend for anti-nuclear activists. Yet, according to estimates of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), one of the most distinguished international authorities in matters of ionizing radiation, there were only 31 early deaths among the plant workers and rescue operators, and no early deaths among the public.

Thirteen years after the accident, apart from an increase in thyroid cancer registry (very likely due to increased screening, rather than a real increase in incidence), there is no evidence of a major public health impact related to the ionizing radiation, and no increase of overall cancer incidence or mortality that could be associated with radiation exposure. There is no scientific proof of any increase in other non-malignant disorders, genetic, somatic, or mental, that could be related to ionizing radiation from Chernobyl. This UNSCEAR (UNSCEAR, 1999) estimate is clearly quite different from what one finds in most media, which prefer to cultivate mass radiophobia—an irrational fear of radiation and all things nuclear. But who reads UNSCEAR reports?

Chernobyl was the worst possible catastrophe of a badly constructed nuclear power reactor: complete core meltdown, followed by free dispersion of radionuclides in the atmosphere, and with an area of lethal fallout, of only 0.5 km^2, reaching up to 1,800 meters from the reactor. Nothing worse could happen with any reactor. It resulted in a comparatively minute death toll, amounting to about half of that of each

TABLE 1
Major Industrial Disasters in the 20th Century

Year	Accident	Site	Number of fatalities
1917	Explosion	Halifax Harbor, Canada	1,654
1921	Explosion in chemical plant	Oppau, Germany	561
1942	Coal-dust explosion	Honkeiko Colliery, China	1,572
1947	Fertilizer ship explosion	Texas City, U.S.A.	562
1956	Dynamite truck explosion	Cali, Colombia	1,100
1957	Nuclear reactor fire	Windscale, U.K.	0
1959	Hydroelectric river dam collapse	Fréjus, France	421
1963	Surge of 108 m^3 water from a reservoir	Vaiont, Italy	2,600
1975	Mine explosion	Chasnala, India	431
1976	Chemical leak (dioxine)	Seveso, Italy	0
1979	Biological/chemical warfare plant accident	Novosibirsk, Russia	300
1979	Nuclear reactor meltdown	Three Mile Island, U.S.A.	0
1984	Natural gas explosion	Mexico City, Mexico	452
1984	Poison gas leak	Bhopal, India	>15,000*
1986	Nuclear reactor meltdown	Chernobyl, Ukraine	31

* *IHT,* 1996.
Source: After Jaworowski, 1996.

Note that most famous disasters, permanently imprinted in public memory, are those with the lowest death toll: Windscale, Seveso, Three Mile Island, and Chernobyl.

weekend's traffic in Poland. When the irrational rumble and emotions of Chernobyl finally settle down, in the centuries to come, this catastrophe will be seen as a proof that nuclear fission reactors are a safe means of energy production. Several accidents at hydroelectric, gas and coal energy production, and other industrial catastrophes in the 20th Century, each caused up to three orders of magnitude greater death toll than the Chernobyl accident (**Table 1**).

In the highly contaminated regions of the former Soviet Union, from which 270,000 people were evacuated and relocated, the 1986-95 average radiation doses from the Chernobyl fallout ranged between 6 and 60 mSv. By comparison, the world's average individual lifetime dose due to natural background radiation is about 150 mSv. In the Chernobyl-contaminated regions of the former Soviet Union, the natural lifetime dose is 210 mSv, while in many regions of the world it is about 1,000 mSv, and in the state of Kerala, India, or in parts of Iran, it reaches 5,000 mSv. Yet no adverse genetic, carcinogenic, or any other deleterious effects of those higher doses have been ever observed among the people, animals, and plants that have lived in those parts since time immemorial (Nair et al., 1999); (Sohrabi, 1990); (Kesavan, 1996); (Cheriyan et al., 1999); (Jaikrishan et al., 1999). The forced evacuation of 270,000 people from their, presumably, poisoned homes, and other forms of overreaction by the Soviet authorities (for example the famous "coffin subsidy"—a monthly financial compensation), did not result in a benefit, but instead caused some real harm: an epidemic of psychosomatic disorders observed in the 15 million people of Belarus, Ukraine, and Russia, such as diseases of endocrinological system, circulatory and gastrointestinal diseases, depression and other psychological disturbances, headaches, sleeping disturbances, difficulties in concentration, emotional instability, inability to work, and so on (Ilyin, 1995); (Ageeva, 1996); (Filyushkin, 1996); (Jaworowski, 1998). The "coffin subsidy," which in impoverished Belarus will total $86 billion by 2015 (Rolevich et al., 1996), for millions of recipients, each time they sign a receipt, confirms that they are the "victims of Chernobyl." The psychosomatic disorders could not be attributed to the ionizing radiation, but were assumed to be linked to the popular belief that any amount of man-made radiation—even minuscule, close to zero doses—can cause harm. This assumption, a linear, no-threshold theory (LNT), was accepted in the 1950s, arbitrarily, as the basis for regulations on radiation and nuclear safety, now still in force. It was under this assumption and regulations (ICRP, 1984a) that the Soviet government decided on the mass relocation of people from regions in which the Chernobyl radiation dose was much smaller than natural radiation background in many countries. This act by the Soviet authorities demonstrated not only the absurdity of LNT, but also the harmful effects of practical application of regulations based on this principle.

During the last three decades, the principles and regulations of radiation protection have gone astray and have led to exceedingly prohibitive, LNT-derived standards and recommendations. Revision of these principles, which is now being proposed by many scientists and several organizations, was evoked both by the eye-opening Chernobyl experience, and by recent progress in radiobiology, genetics, and oncology. Radiation carcinogenesis should no longer be perceived as a straightforward process started by a random hit by radiation to the DNA double strand in the cell. The complexity of this process precludes the use of direct proportionality, even to estimate the probability of the malignant cell becoming a macroscopic, clinically verifiable tumor. After a total malignant transformation, the cell has to divide some billions of times, before a cancer is formed. Such transformed cells appear to be distant from cancer by so many billions of iterative steps, that their outcome cannot be predicted, as a matter of principle (Walinder, 1995).

A great radiobiologist, the late Harald Rossi, summarized the situation as follows: "It would appear . . . that radiation carcinogenesis is an intricate intercellular process and that the notion that it is caused by simple mutations in a unicellular response is erroneous. Thus, there is no scientific basis for the 'linearity hypothesis' according to which cancer risk is proportional to absorbed dose and independent of dose rate at low doses" (Rossi and Hald, 1984).

One of the factors responsible for these winds of change is the recognition by many scientists that small doses of radiation, like small doses of other physical or chemical agents, may be beneficial for organisms, and may evoke a stimulatory or hormetic response, which is in direct opposition to the LNT. About 2,000 scientific papers on radiation hormesis were published in the 20th Century. However, when in 1982 I proposed that UNSCEAR should review and assess these papers, nobody seemed interested. Each following year, I repeated this proposal in vain, until after Chernobyl, in 1987, it finally gained support from the representatives of France and Germany. It took UNSCEAR some dozen years of deliberations before, in 1994, the committee published its fundamental report (UNSCEAR, 1994), rubberstamping the very existence of the phenomenon of hormesis. It was difficult for the committee to overcome its own prejudices on radiation hormesis, and to produce a balanced objective report.

Along the way, the committee rejected two rather one-sided drafts of a "hormesis document," and in 1990, also an excellent document on "Hereditary Effects of Radiation," prepared by a leading expert in the field, Prof. F. Vogel. This last rejection demonstrated the hesitance of the committee, as Vogel's paper showed a lack of genetic effects after the Chernobyl accident, and presented the existence of hormetic effects in children of Hiroshima and Nagasaki survivors, as well as the lack of any hereditary disorders both in these children, and in inhabitants of high natural background radiation areas. The draft of the UNSCEAR 1994 "hormetic report" was prepared by Dr. Hylton Smith, then the Scientific Secretary of the International Commission on Radiological Protection (ICRP), a body strongly supporting LNT and rejecting hormesis. However, while working for a few years on this report, Dr. Smith changed his initially negative approach to radiation hormesis, and finally produced an excellent, unbiased treatise on this yet-unfathomed matter, demonstrating his scientific integrity. This report sparked a quasi revolution in the radiation protection community, which is now gaining momentum, with some encouragement from the chairman of ICRP, Prof. Roger Clarke (Clarke, 1999).

Natural and Man-Made Radiation

The linear no-threshold hypothesis was accepted in 1959 by the ICRP as a philosophical basis for radiological protection (ICRP, 1959). This decision was based on the first report of the then just established UNSCEAR Committee (UNSCEAR, 1958). A large part of this report was dedicated to a discussion of linearity and of the threshold dose for adverse radiation effects. UNSCEAR's stand on this subject, more than 40 years ago, was formed after an in-depth debate, not, however without any influence of the political atmosphere and issues of the time. Soviet, Czechoslovakian, and Egyptian delegations to UNSCEAR strongly supported the LNT assumption, using it as a basis for recommendation of an immediate cessation of nuclear test explosions. The then prevailing target theory and the then new results of genetic experiments with fruit flies irradiated with high doses and dose rates, strongly influenced this debate. In 1958, UNSCEAR stated that contamination of the environment by nuclear explosions increase radiation levels all over the world, posing new and unknown hazards for present and future generations. These hazards cannot be controlled, the report said, and "even the smallest amounts of radiation are liable to cause deleterious genetic, and perhaps also somatic, effects." This sentence had an enormous impact in the next decades, being repeated in a plethora of publications, and taken even now as an article of faith by the public.

However, throughout the 1958 report, the original Unscear view on LNT remained ambivalent. As an example, UNSCEAR accepted as a threshold for leukemia a dose of 4,000 mSv (p. 42), but at the same time the committee accepted the risk factor for leukemia of 0.52% per 1,000 mSv, assuming LNT (p. 115). The committee quite openly presented this difficulty, showing in one table (p. 42) its consequences: Continuation of nuclear weapon tests in the atmosphere was estimated to cause 60,000 leukemia cases worldwide if no threshold is assumed, and zero leukemia cases if a threshold of 4,000 mSv exists. In its final conclusions, UNSCEAR pinpointed this situation: "Linearity has been assumed primarily for purposes of simplicity" and "There may or may not be a threshold dose. Two possibilities of threshold and no-threshold have been retained because of the very great differences they engender."

In the ICRP document of 1959, no such controversy appears; LNT was arbitrarily assumed, and serious epistemological problems related to the impossibility of finding harmful effects at very low levels of radiation, later discussed by Weinberg (1972) and Walinder (1987), were ignored. Over the years, the working assumption of ICRP of 1959 came to be regarded as a scientifically documented fact by mass media, public opinion, and even many scientists. The LNT principle, however, belongs to the realm of administration and is not a scientific principle.

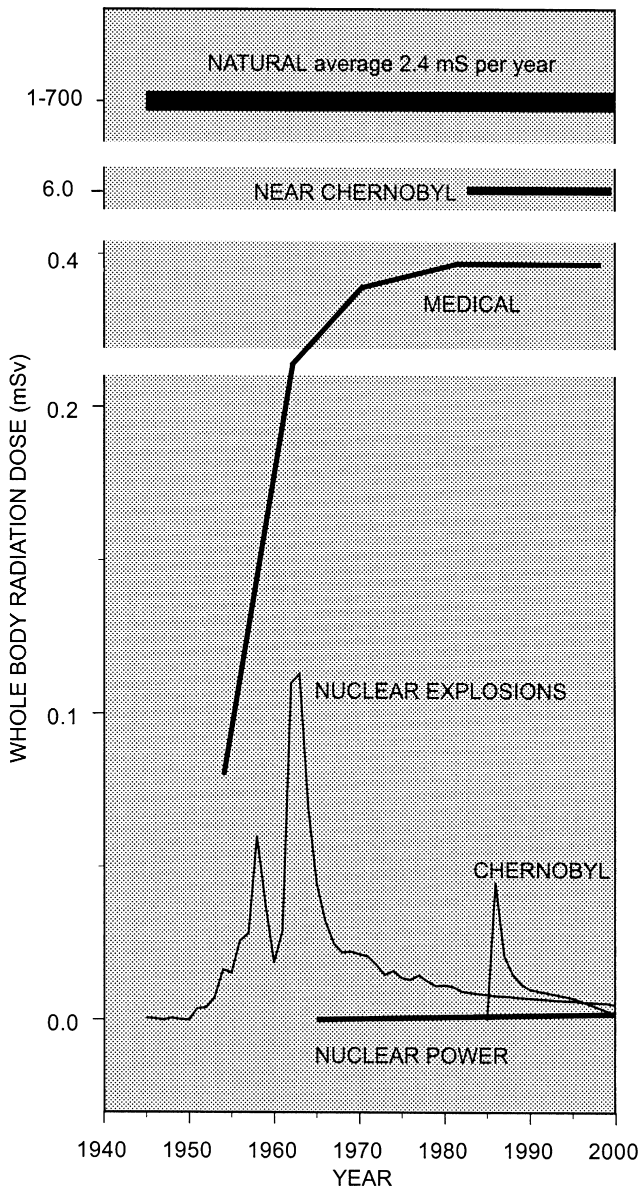
In these early years, the LNT assumption did not seem very realistic, but was generally accepted, because it simplified regulatory work. The original purpose was to regulate the exposure to radiation of a relatively small group of occupationally exposed persons, and it did not involve exceedingly high costs. In the 1970s, however, ICRP extended the LNT principle to exposure of the general population to man-made radiation, and in the 1980s, it extended LNT limiting the exposure to natural sources of radiation (ICRP, 1984b).

In the same document, ICRP recommended restriction of radiation exposure of members of the public to 1 mSv per year, that is below the average annual global natural radiation dose of 2.2 mSv, and many tens or hundreds of times lower than the natural doses in many regions of the world. Such an absurdly low limitation of exposure was a logical consequence of the administrative LNT assumption from 1959. It made a false impression on the public, that new research steadily discovers a greater harmfulness of radiation, which needs more protection, more money, and lower standards. In fact, nothing like this occurred.

Since the introduction of rational standards in the 1930s, which were based on a tolerance dose concept, and were orders of magnitude higher than now, no deleterious effects were found among those that observed them (Taylor, 1981). This constant decreasing of standards, however, was less than palatable to many scientists associated with radiation protection, standing both on purely scientific and practical grounds.

One of the important factors in changing the opinion of many scientists was finding actual proportions between man-made and natural exposures. Data published in the UNSCEAR documents clearly show that the average individual global radiation dose in the 1990s from nuclear explosions, the Chernobyl accident, and commercial nuclear plants combined was about 0.4% of the average natural dose of 2.2 mSv per year. In areas of the former Soviet Union that were highly contaminated by Chernobyl fallout, the average individual dose was much lower than that in regions with high natural radiation. The greatest man-made contribution to radiation dose has been irradiation from x-ray diagnostics in medicine, which accounts for about 20% of the average natural radiation dose (**Figure 1**). From the medical point of view, it does not matter whether ionizing radiation comes from natural or from man-made sources; its nature is the same. We do not observe any adverse effects of irradiation from Mother Nature's sources: No increase of cancers and hereditary disorders was ever found in natural high-radiation areas. The concern about large doses, such as absorbed by three workers in Tokaimura or by 28 fatal radiation victims in Chernobyl, is obviously justified. But should we spend

FIGURE 1
Average Annual Global Radiation Doses from Natural and Man-Made Sources



Natural exposure is assumed to be stable. The temporal trends in local Chernobyl exposures are not presented.

enormous funds to protect people against radiation corresponding to tiny fractions of natural doses, only because humans make them?

A few billion years ago, when life on Earth began, the natural level of ionizing radiation was about three to five times higher than it is now (Karam, 1999). At the early stages of evolution, increasingly complex organisms developed powerful defense mechanisms against adverse effects of this radiation, and of all kinds of environmental factors, for example against toxicity of oxygen and other innumerable inorganic and organic toxins, and dangerous physical agents, including the whole range of the radiation energy spectrum. Living organisms developed not only protective mechanisms against these environmental agents, but they learned how to use them to their advantage. We see this readily in the case of visible light and UV radiation. UV radiation belongs to the ionizing part of the spectrum. It is rather doubtful that other types of ionizing radiation were excluded from this evolutionary adaptive process. The phenomenon of radiation hormesis observed in man, and in animals, argues against such exclusion. On the other hand, that the evolution proceeded for so long is proof of the effectiveness of living things' defenses against environmental agents, including ionizing radiation.

The adverse effects of ionizing radiation, such as mutation and malignant change, originate in the cell nucleus, where the DNA is their primary target. Other adverse effects, which lead to acute radiation sickness and premature death in humans, also originate in the cell, but outside its nucleus. For them to take place requires radiation doses thousands of times higher than those from natural sources. A nuclear explosion or a cyclotron beam could deliver such a dose; so could a defective medical or industrial radiation source—Tokaimura and Chernobyl are two examples. An artificial distinction between these two types of effects, 1) starting in the DNA of the cell nucleus, and 2) outside the nucleus, was made by introducing terms of "stochastic effects" for late malignant and hereditary changes, and "deterministic effects" for early acute changes and cataracts (ICRP, 1977). Medicine does not recognize such a distinction. In fact, it was a tacit introduction of the LNT thinking template into radiation protection. By definition, stochastic (probabilistic) effect is "an all-or-nothing effect, the severity of which does not vary with dose" (NCRP, 1995), and which distinguishes them from "deterministic" effects, the severity of which increases with dose.

However, both notions—stochastic and deterministic effects—seem rather empty and obsolete, in view of the new information on mechanisms of carcinogenesis and genetics. The lack of dose-related severity in stochastic effects—the main difference between them and deterministic effects—is simply not true. As demonstrated by Walinder (1995), many radiogenic cancers in man and in experimental animals show greater histologic and clinical malignancy after high-radiation doses than after smaller ones. Also, latency time is shortened when the dose increases, so the malignant tumors can have more time to develop during a lifetime.

According to recent studies, by far the most DNA damage in humans is spontaneous and is caused by thermodynamic decay processes and by reactive free radicals formed by oxygen metabolism. Each mammalian cell suffers about 70 million spontaneous DNA-damaging events per year (Billen, 1994). More recent measurements of steady state oxygen free radical damages to DNA (Helbock et al., 1998) and their repair rates (Jaruga, Dizderoglu, 1996) demonstrate about 350 million metabolic DNA oxidamages per cell per year. Only if armed with a powerful defense system could a living organism survive such a high rate of DNA damage. An effective defense system consists of mechanisms that repair DNA, and other homeostatic mechanisms that maintain the integrity of organisms, both during the life of the individual and for thousands of generations. Among those homeostatic mechanisms are antioxidants, enzymatic reactions, apoptosis (suicidal elimination of changed cells), immune system removal of cells with persistent DNA alterations, cell cycle regulation, and intercellular interactions.

Ionizing radiation damages DNA also, but at a much lower rate. At the present average individual dose rate of 2.2 mSv per year, natural radiation could be responsible for no more than about 5 DNA-damaging events in one cell per year. Why, with a background of 70 million spontaneous DNA damages per cell per year, should we protect people against 2.3 DNA damages per cell per year, expected from the 1 mSv annual dose limit recommended by ICRP? Though spontaneous repairing of double-strand break damages of DNA occurs rarely, compared to their occurrence in radiation damage, spontaneous oxygen metabolism induces about 1,000 timeas as many double-strand breaks as background radiation (Stewart, 1999). In this perspective, even a limit permitting 200 DNA damages per cell per year, or 100 mSv per year, would be proper.

As compared with other noxious agents, ionizing radiation should be regarded as rather feeble. The safety margin for ionizing radiation is much larger than for many other agents present in the environment, e.g., thermal changes, plant and animal poisons, or heavy metals. For example, a toxic level of lead in blood is only three times higher than its "normal" level. A lethal dose of ionizing radiation delivered in one hour—which for an individual human is 3,000 to 5,000 mSv—is a factor of 10 million higher than the average natural radiation dose received in the same time (0.00027 mSv). Nature seems to have provided living organisms with an enormous safety margin for natural levels of ionizing radiation—and also, adventitiously, for man-made radiation from controlled, peacetime sources. Conditions in which levels of ionizing radiation could be noxious, do not normally occur in the biosphere, so humans required no radiation-sensing organ and none evolved, although all species have always been immersed in the sea of radiation ever since life began.

Why Radiophobia?

If radiation and radioactivity, though ubiquitous, are so innocuous at normal levels, why do they cause such universal apprehension? What is the cause of radiophobia, an irrational fear that any level of radiation is dangerous? Why have radiation protection authorities introduced a dose limit for the public of 1 mSv per year, which is less than half the average dose rate from natural radiation, and less than 1% of the natural dose rates in many areas of the world? Why do the nations of the world spend many billions of dollars a year to maintain this standard (Cohen, 1992; Hezir, 1995)? In a recent paper, I proposed some likely reasons (Jaworowski, 1999):

- the psychological reaction to devastation and loss of life caused by the atomic bombs dropped on Hiroshima and Nagasaki at the end of World War II;
- psychological warfare during the Cold War, which played on the public's fear of nuclear weapons;
- lobbying by fossil fuel industries;
- the interests of radiation researchers striving for recognition and budget;
- the interests of politicians for whom radiophobia has been a handy weapon in their power games (in the 1970s in the U.S.A., and in the 1980s and 1990s in eastern and western Europe and in the former Soviet Union);
- the interest of news media that profit by inducing public fear;
- the interest of "greens" that profit by inducing public fear;
- the assumption of a linear, no-threshold relationship between radiation and biological effects (LNT).

In addition, a very important factor was:

- the complaisance of the nuclear industry leadership, paralyzed by anti-nuclear propaganda. Intimidated industry accepted irrational standards, and did not develop research programs to check the validity of LNT.

During the past five decades, nuclear weapons were regarded as a deterrent, and the countries that possess them wished to make radiation and radioactivity seem as dreadful as possible. Therefore, national security agencies seldom correct even the most obviously false statements, such as that often voiced: "Radiation from a nuclear war can annihilate all mankind, or even all life," or (the ever-authoritative *International Herald Tribune*) "200 grams of plutonium could kill every human being on Earth" (Koning, 1996). The facts say otherwise. According to UNSCEAR reports, between 1945 and 1980, the 541 atmospheric nuclear tests injected into the global atmosphere about 3,000 kilograms of plutonium (that is, almost 15,000 supposedly deadly 200 gram doses), yet lo and behold: Somehow we are still alive! (Try to publish this in the *International Herald Tribune:* no way!)

According to UNSCEAR data, from all these 541 atmospheric explosions with a total energy yield of 440 megatons of TNT, we accumulated, between 1945 and 1998, an average individual radiation dose of about 1 mSv, which is less than 1% of the dose from natural sources over the same period. In the heyday of atmospheric testing, 1961 and 1962, there were 176 atmospheric explosions, with a total energy yield of 84 megatons. The average individual dose accumulated from the fallout between 1961 and 1964 was about 0.35 mSv.

At its Cold War peak of 50,000 weapons, the global nuclear arsenal had a combined potential explosive power of about 13,000 megatons, which was only 30 times larger than the megatonnage already released in the atmosphere by all previous nuclear tests. If that whole global nuclear arsenal had been deployed in the same places as the previous nuclear tests, the average individual would have received a lifetime radiation dose from the global fallout of about 30 to 55 mSv, a far cry from the short-term dose of 3,000 mSv that would kill a human.

For several decades, humanity has lived under the gloomy shadow of imminent nuclear annihilation. This has had an extremely negative influence not only on public perception of radiation and nuclear energy, but induced a cultural change: distrust of science, rejuvenation of irrational apocalyptic mythologies, and even an aversive approach to civilization, the fruit of toil and sweat of ourselves and of our forefathers.

Hiroshima, Nagasaki, and LNT

The survivors of the atomic bombing of Hiroshima and Nagasaki who received instantaneous radiation doses of less than 200 mSv have not suffered significant induction of cancers (Cohen, 1998). Among 59,539 inhabitants of these two cities who absorbed doses up to 1990 mSv, 119 persons died between 1950 and 1985, due to leukemia, i.e., about 0.006% per year, and 4,319 persons died due to all other cancers, i.e., 0.2% (Shimizu et al., 1989). According to Polish Cancer Registry data, in 1993, 0.006% people died in Poland due to leukemia, and about 0.2% due to all other cancers (Zatonski and Tyczynski, 1996). This comparison shows that with doses of up to nearly 2,000 mSv, we should not expect any detectable epidemic of malignancies. Among the bomb survivors irradiated with doses lower than 150 mSv, mortality caused by leukemia was lower (although statistically not significant) than among the non-irradiated inhabitants of two Japanese cities (UNSCEAR, 1994). A slight, but non-significant, decrease in overall non-cancer mortality among bomb survivors exposed to low and intermediate doses can also be seen in the data of the Atomic Bomb Casualty Commission and the Radiation Effects Research Foundation (Kondo, 1993; Shimizu et al., 1992). So far, after 50 years of study, the progeny of Japanese survivors who were exposed to these and much higher, near-lethal doses, had not developed any adverse genetic effects (Sankaranarayanan, 1997).

Until recently, such findings from the study of A-bomb

"Should we spend enormous funds to protect people against radiation corresponding to tiny fractions of natural doses, only because humans make them?" Here, a shipment of low-level radioactive waste.

survivors has been consistently ignored. In place of the actual findings, has been the theory of linear no-threshold (LNT), which presumes that the detrimental effects of radiation are proportional to the dose, and that there is no dose at which the effects of radiation are not detrimental. LNT theory played an important role in effecting first a moratorium, and then a ban on atmospheric nuclear tests. But otherwise, its role was mostly negative, inducing worldwide fear of radiation and effective strangulation of development of nuclear energy systems in many countries, including the United States. My own country, Poland, spent billions of dollars on construction of its first nuclear power station, only to abandon the project after politically motivated manipulation of the public opinion by means of the LNT theory.

The mechanism of inducing fear is quite simple. For example, one calculates, very exactly, that 28,000 people would die of Chernobyl-induced cancers over the next 50 years, and news media trumpet this, or much greater values all over the world, now and again, and ad nauseam. The frightening death toll was derived by multiplying the trifling Chernobyl doses in the Northern Hemisphere, including Canada and the United States (0.0046 mSv per person) by the vast number of people leaving there and by a cancer risk factor based on epidemiological studies of 75,000 atomic bomb survivors in Japan (Goldman et al., 1987). But the A-bomb survivor data are irrelevant to such estimates, because of the difference in the individual doses and dose rates. A-bomb survivors were flashed within about one second by radiation doses at least 50,000 times higher than the dose which U.S. inhabitants will ever receive, over a period of 50 years, from the Chernobyl fallout.

We have reliable epidemiological data for a dose rate of, say, 6,000 mSv per second in Japanese A-bomb survivors. But there are no such data for human exposure at a dose rate of 0.0046 mSv over 50 years (nor will there ever be any). The dose rate in Japan was larger by 2×10^{15} than the Chernobyl dose rate in the U.S.A. Extrapolating over such a vast span is neither scientifically justified nor epistemologically acceptable. It is also morally suspect (Walinder, 1995).

An offspring of the LNT assumption is the concept of dose commitment, introduced in early 1960, and of collective dose. Dose commitment reflected the great concern, at that time, that harmful hereditary effects could be induced by fallout from nuclear tests. The concern was so great that, according to definition, dose commitment values were to be calculated for periods of time ending in infinity. In later years, the individual dose commitments, and collective dose commitments, also for some truncated periods, were calculated mainly for exposures from nuclear power. For example, UNSCEAR calculated 205,000 man Sv [a unit of collective dose and of dose commitment] for the next 10,000 years from power reactors and reprocessing plants, 600,000 man Sv from Chernobyl fallout in the Northern Hemisphere for eternity, and 650,000,000 man Sv for the world's population from only the past 50 years of exposure to natural radiation. These large values, terrifying as they are to the general public, provide society with no relevant biological or medical information. Rather, they create a false image of the imminent danger of radiation, with its all actual negative social and psychosomatic consequences.

But why stop at 50 years in calculating dose commitments for natural radiation, when, for man-made radiation, one makes estimates over infinite time? For example, the individual dose commitment, supposedly accumulated over the past 130,000 years of existence of the modern *Homo sapiens,* and calculated for the average human now living, is 286,000 mSv, i.e., about a hundred short-term lethal doses. Each of us is burdened with this or a similar value of dose commitment. Do these values represent anything real, or are they just figments of scholastic fantasies? What are the medical effects of these enormously high doses? I proposed in a recent paper (Jaworowski, 1999), that the intellectually invalid concepts of collective dose and dose commitment be hacked off with William of Occam's razor.

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