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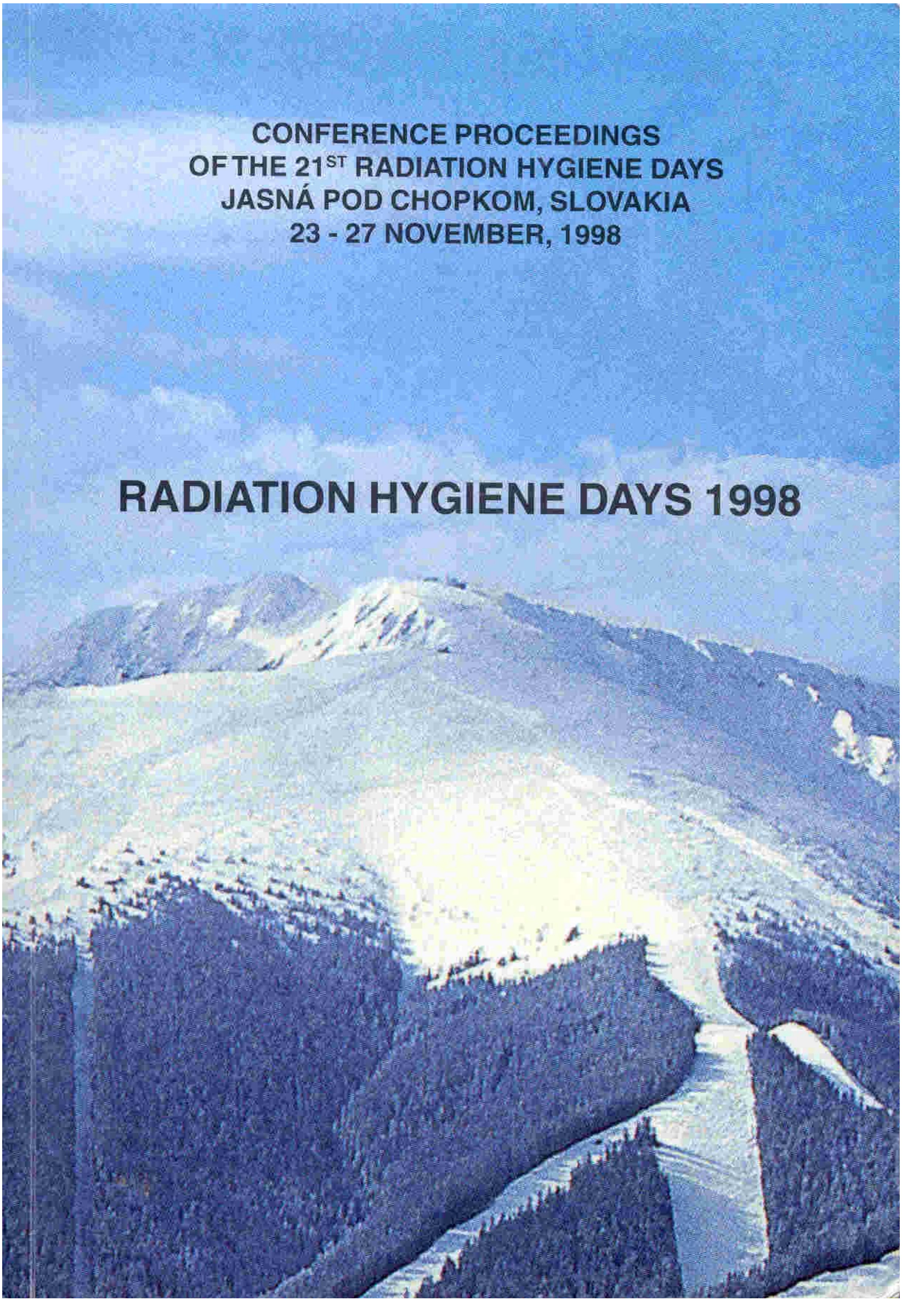
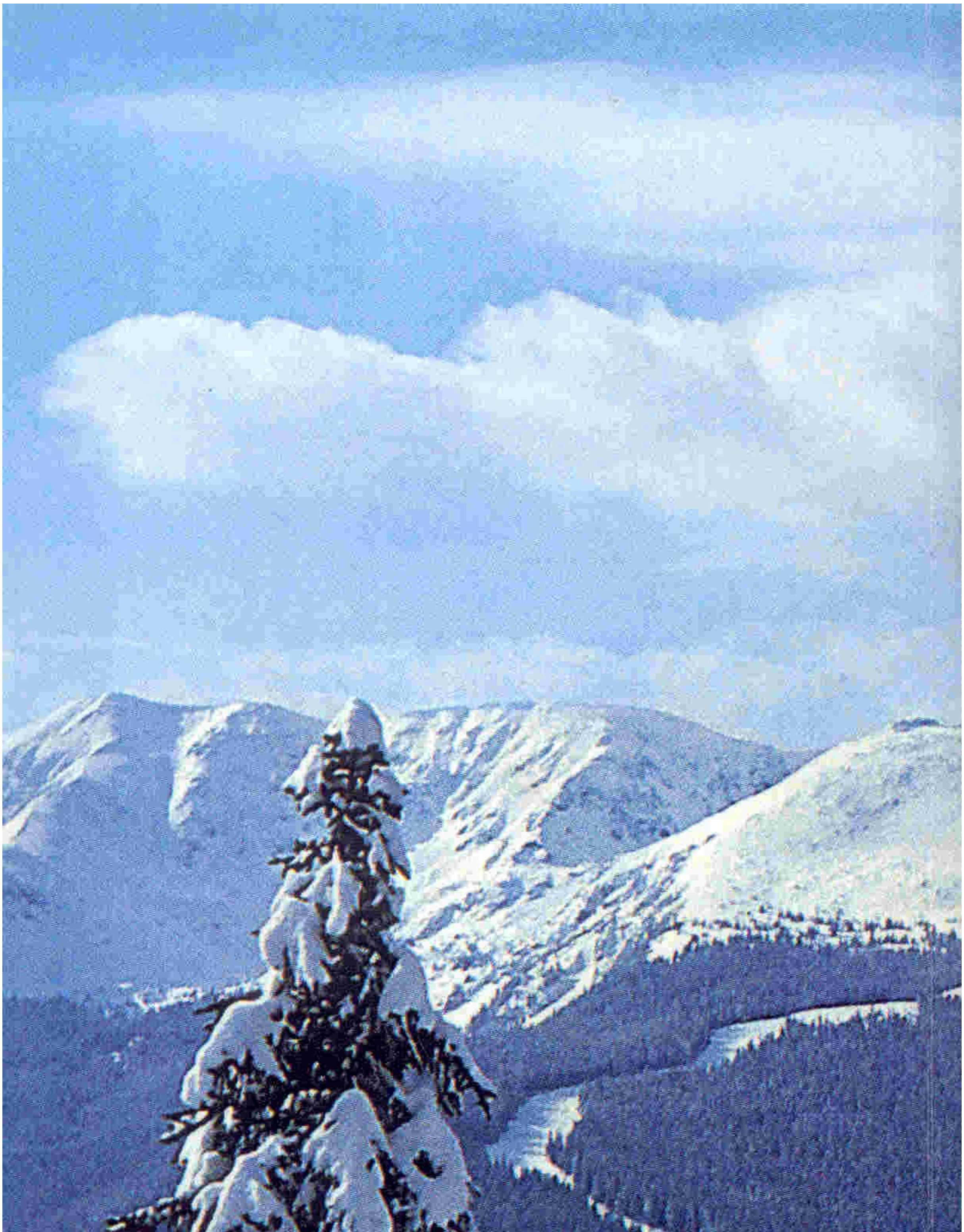
OF THE 21ST RADIATION HYGIENE DAYS
JASNÁ POD CHOPKOM, SLOVAKIA
23 - 27 NOVEMBER, 1998

RADIATION HYGIENE DAYS 1998





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CONTENS

WHAT IS MORE DANGEROUS: NUCLEAR POWER PLANTS OR CARBON FIRED POWER PLANTS?

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The aim of this paper is to compare environmental impacts of radionuclides and other pollutants released into environment from nuclear power plants (NPP) and coal fired power plants (CFPP).

Global energy in 1993 reached 338 exajoules; it is 40% greater than in 1973 [1]. In the next table primary energy consumption by fuel in 1997 is compared [2].

Table 1. Primary energy consumption by fuel in 1997 (million tons of oil equivalent)

Oil	Natural Gas	Coal	Nuclear Energy	Hydroelectric power	Total
3395.5	1977.3	2293.4	617.4	225.4	8509.2
39.90 %	23.24 %	26.95 %	7.26 %	2.65 %	

Coal combustion continues to be dominant fuel source for electricity production. Fossil fuel's share has decreased ftom 76.5% in 1970 to 66.3% in 1970, while nuclear energy's share in the global electricity has increased from 1.6% in 1970 to 17.4% in 1990.

Today, NPPs provides about 18% of the world's electricity 340.347 MWe [3]. It offers an important environmental advantage in that it produces no harmful emissions as carbon dioxide (CO_2), sulphur dioxide (SO_2) or nitrogen dioxide (NO_x) in normal operation. According to calculation, if the electricity currently generated by nuclear power plants globally were, instead, to be produced by burning coal, another 8%, or $1.6x10^9$ tons of carbon dioxide, would be injected into the earth's atmosphere (annually).

World-wide, there were 443 nuclear power reactors in operation at the start of 1997, producing about as much electricity as obtained from hydropower [3]. A large power reactor (1000 MW_e) uses 150 tons of natural uranium a year, equivalent to 2.5 million tons of black coal or 12 million barrels of oil (1.908 million m^3 of oil) [4].

The supply of nuclear power is to increase 2.5 times between 1989 and 2010 with a target of 30% of all electricity being generated by nuclear power by the year 2010 [4].

At the combustion of coal and other fossil fuels arising enormous amounts of greenhouse gases, as carbon dioxide, nitrogen oxides and other pollutants, as sulphur dioxide.

The increasing use of nuclear power since 1960s, combined with steady increases hydropower, have helped curb world-wide carbon dioxide output. If the electricity energy generated worldwide each year were produced in NPPs instead by coal-powered plants, there would be additional emissions of 1,600 million tons of CO_2. If the world were not employing nuclear power today, global carbon dioxide emissions would be at least 8% greater every year.

Nuclear power is exceptionally clean in operation. Concern is usually focused on the highly toxic and radioactive spent fuel and nuclear wastes. In addition to their toxicity and radioactivity, they are limited in volume, which facilitates waste disposal. This contrasts sharply with the waste disposal problem for fossil-fuelled plants. For example:

A 1 000 MW_e CFPP with optimal pollution abatement equipment will emit into the atmosphere 900 tons of SO_2 per year; 4500 tons of NO_x; 1300 tons of particulates; and 6.5 million tons of CO_2. Depending on the quality of the coal. up to one million tons of ashes containing hundreds of tons of toxic heavy metals (arsenic, cadmium, lead) and natural radionuclides (uranium, thorium, daughter radionuclides, K-40) will have to be disposed of [5].

By contrast, a NPP of 1 000 MW .capacity produces annually some 35 tons of highly radioactive spent fuel. If the spent fuel is reprocessed, the volume of highly radioactive waste will be about 3 m^3. The entire nuclear chain supporting this 1000 MW_e plant, from mining through operation, will generate, in addition, some 200 m^3 of intermediate level waste and some 500 m^3 of low level waste per year [5].

In 1992, global emissions of CO_2 - the prime greenhouse gas added to the atmosphere as a direct result ofhuman activity - amounted to 26.4 x 10^9 tons per year, of which 84% (22.3 x 10^9 tons) was from industrial activity. Emissions from industrial activity have climbed 38 percent over the past 20 years. The United States had the highest per capita emissions - 19.1 tons per year -among the nations that were the major sources of global emissions in 1992 [1]. In the Slovak Republic the combustion of fossil fuels is a source of about 94 % emissions of carbon dioxide, - 58.3 million tons CO_2 annually. Slovakia with its production of 11 tons of CO_2 per capita in 1990 highly had surpassed then European mean value 7.3-tons/capita.year [6].

With regard to environmental impacts, nuclear power offers specific benefits. In routine operation, nuclear power plants and the fuel cycle facilities do release small quantities of radionuclides, mostly there are radioisotopes of inert gases Xe, Kr and iodine. However, the rules developed and implemented several decades ago for limiting radioactive emissions satisfy criteria for protecting human health and more than adequate to protect the environment. The other emissions, residuals, and burdens from NPPs and fuel cycle facilities are lower than those arising from fossil-fuel electricity generations chains and comparable or lower than those from renewable energy systems. Taking into account the entire up-stream and down-stream energy chains for electricity generation. nuclear power emits 40 to 100 times less CO_2 than currently used fossil-fuel chains [1 0]. Greenhouse gas emissions from the nuclear chain are due mainly to the use of fossil fuels in the extraction, and enrichment of uranium and to fuels used in the production of steel, cement and other materials for the construction of reactors and fuel cycle facilities. These emissions, which are negligible relative to those from the direct use of fossil fuels for electricity generation. can be reduced even further by energy efficiency improvement [12].

From a point of view conservation of the environment it is important what area would be need for a power plant. This value depends from energy density: 1 kg of firewood produces about 1 kWh of electricity; 1 kg of coal produces about 3 kWh of electricity; 1 kg of oil produces about 4 kWh of electricity; 1 kg of natural uranium produces about 50 MWh of electricity; and 1 kg of plutonium produces 'about 6 GWh.

The low energy density of the renewable sources means that if we want significant amounts of energy (electricity) from them, we must "harvest" them over large areas - and this is very expensive. It has been calculated that to achieve the electricity generating capacity of a 1000 MW .power plant, we would need: an area of 50 to 60 km^2 to install solar cells or windmills, or an area of 3000 to 5000 km^2 to grow the needed biomass [5]. By contrast, we would need an area of only a few square kilometres for a NPP, including aIl of its fuel cycle requirements.

Coal is one of the most Ímpure of fuels. Its impurities range from trace quantities of many metals, including natural radionuclides uranium and thorium, to much larger quantities of Al and Fe to still larger quantities of impurities such as sulphur. Products of coal combustion include the oxides of carbon, nitrogen, and sulphur; carcinogenic and mutagenic substances; and recoverable minerals of commercial value, including nuclear fuels naturaIly occurring in coal.

Coal ash is composed primarily of oxides of silicon, aluminium, iron, calcium, magnesium, titanium, sodium, potassium, arsenic, mercury, other metals, and sulphur plus small quantities of uranium and thorium. Fly ash is primarily composed of non-combustible silicon compounds (glass) melted during combustion. Tiny glass spheres form the bulk of the fly ash.

Since the 1960s particulate precipitators have been used by CFPPs to retain significant amounts of fly ash rather than Ietting it escape to the atrnosphere. When functioning properly, these precipitators are approximately 99.5% efficient. Utilities also collect furnace ash, cinders, and slag, which are kept in cinder piles or deposited in ash ponds on coal-plant sites along with the captured fly ash.

Trace quantities of uranium in coal range from less than 1 ppm in some samples to around 10 ppm in others. In some cases a concentration of uranium can to amount up to 1000 ppm [11] and they can be used as uranium resources. Generally, the amount of thorium contained in coal is about 2.5 times greater than the amount of uranium. For a large number of coal samples, according to Environmental Protection Agency figures released in 1984, average values of uranium and thoriurn content have been determined to be 1.3 ppm and 3.2 ppm, respectively. Using these values along with reported consumption and projected consumption of coal by utilities provides a means of calculating the amounts of potentially recoverable breedable and fissionable elements. The concentration of fissionable U-235 (the current fuel for NPPs) has been established to be 0.71 % of U content. In the coals mined in the Slovakia (3.8 million tons in 1996) concentrations of natural radionuclides were determined in previous years, but these values so far were not published [7]. And what about ~3.8 million tons of coal imported into Slovakia yearly?

Assume that the typical plant has an electrical output of 1000 MW. Existing coal-fired plants ofthis capacity annually burn about 4 rnillion tons of coal each year.

Using these data, the releases of radioactive materials per typical plant can be calculated for any year. For the year 1990, assurning coal contains uranium and thorium concentrations of 1.3 ppm and 3.2 ppm, respectively, each typical plant 1000 MW_e released 5.2 tons of U (containing 36.92 kg of U-235) and 12.8 tons of Th that year. Total releases in 1990 from worldwide combustion of -3300 rnillion tons of coal totalled ~4552 tons of uranium (containing ~32317 kg of U-235) and ~10860 tons of thorium. These values continually increased!

Based on the predicted combustion of 12,580 rnillion tons worldly during the year 2040, cumulative releases for the 100 years of coal combustion following 1937 are predicted [9] to be Planetary release (from 'combustion of 637,409 million tons): Uranium: 828,632 tons (containing 5883 tons of U-235); Thorium: 2,039,709 tons.

On the base these amounts McBridge et al. concluded that "Americans living near CFPPs are exposed to higher radiation doses than those living near NPPs that meet government regulation [9].

The main sources of radiation released from coal combustion include not only uranium and thorium but also daughter products produced by the decay of these nuclides, such as isotopes of radium, radon, polonium, bismuth, and lead. Although not a decay product, naturally occurring radioactive potassium-40 is also a significant contributor.

According to the National Council on Radiation Protection and Measurements (NCRP), the average radioactivity is 427 ~Ci/t of coal. This value can be used to calculate the average expected radioactivity release from coal combustion. For 1990 the total release of radioactivity from worldwide 3300 million tons coal combustion was, therefore, about 1.41 MCi.

For comparison, according to NCRP Reports No. 92 and No. 95, population exposure from operation of 1000-MW. NPP and CFPPs amounts to 4.90 man-Sv/year for CFPPs and 0.048 man-Sv/year for NPPs. Thus, the population effective dose equivalent from CFPPs is 100 times that from NPPs. For the complete nuclear fuel cycle, from mining to reactor operation to waste disposal, the radiation dose is cited as 1.36 man-Sv/year [13, 14]; the equivalent dose for coal use, from mining to power plant operation to waste disposal, it is probably unknown.

During combustion, the volume of coal is reduced by over 85%, which increases the concentration of the metals originally in the coal. A global average concentration of uranium is 10 ppm in ash [15]. Although precipitators retain significant quantities of ash, heavy metals such as uranium and thorium tend to concentrate on the tiny glass spheres that make up the bulk of fly ash. This uranium is released to the atmosphere with the escaping fly ash, at about 1.0 % of the original amount, according to NCRP data. The retained ash is enriched in uranium several times over the original uranium concentration in the coal because the uranium, and thorium, content is not decreased as the volume of coal is reduced. Fly ash (with U and Th and daughter radionuclides are precipitated with snow and rain and increased activity of air and Earth's surface.

Another unrecognised problem is the gradual production of Pu-239 through the exposure of U-238 in coal waste to neutrons from the air. These neutrons are produced primarily by bombardment of oxygen and nitrogen nuclei in the atmosphere by cosmic rays and from spontaneous fission of natural isotopes in soil. Because Pu-239 is toxic in micro-quantities, this process, however slow, is potentially very dangerous. The radiotoxicity of Pu-239 is 3.4×10^{11} times that of U-238. Consequently, for ~4552 tons of uranium released in 1990, only 2.2 milligrams ofPu-239 bred by natural processes is necessary to double the radiotoxicity estimated to be released into the biosphere by year. Natural processes to produce both Pu-239 and Pu-240 appear to exist.

For the 100 years following 1937, world use of coal as a heat source for electric power generation will result in the distribution of enormous radionuclides into the environment. This is very important problem and it is questionable about the risks and benefits of coal combustion, as source of electricity production. The potential health effects of released naturally occurring radionuclides are a long-term issue that has not been fully solved. Even with improved efficiency in retaining stack emissions, the removal of coal from its shielding overburden in the earth and subsequent combustion releases large quantities of radioactive materials to the surface of the earth. The emissions by CFPPs of greenhouse gases, a vast array of chemical by-products, and naturally occurring radionuclides make coal much less desirable as an energy source than is generally accepted. Large quantities of uranium and thorium and other radioelements in coal ash are not being treated as radioactive waste. These products emit low-Ievel radiation, but because of regulatory differences, CFPPs are allowed to release quantities of radioactive material that would provoke enormous public outcry if such amounts were released from nuclear facilities. Nuclear waste products from coal combustion are allowed to be dispersed throughout the biosphere in an unregulated manner. Collected nuclear wastes that accumulate on electric utility sites are not protected from weathering, thus exposing people to increasing quantities of radioactive isotopes through air and water movement and the food chain [8]. The fact that large quantities of uranium and thorium are released from CFPPs without restriction increases a paradoxical situation. Considering that the nuclear power industry has been compelled to invest in expensive measures to greatly reduce releases of radionuclides from nuclear fuel and fission products to the environment, should coal-fired power plants be allowed to do so without constraints!

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