OUR NUCLEAR FUTURE: THE PATH OF SELECTIVE IGNORANCE

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Abstract

Well-established trends in world energy consumption indicate long-term commitments to combustion of fossil fuel[1]. Industrialized nations are currently the major users of coal, but early in the 21st century a shift in usage is predicted such that today's developing countries will be the primary users. For example, China has large reserves of coal and currently accounts for about 24% of world combustion with plans to increase its consumption to eight times more than 1990 combustion by the year 2020[2]. Global coal resources are projected to provide about 1500 years supply at the current use rate[3]. Current US energy policy favors fossil fuel for large base-load electric power production, and almost 90% of the coal consumed in the US today is burned at electric power utilities[4]. Global coal production will continue to exceed the US rate by more than a factor of five[5].

While effects of fossil fuel combustion continue to be studied and debated, US environmental protection and reclamation law, resource conservation and recovery law, along with energy conservation law, pose conflicts in policy direction that selectively ignore various consequences. Although chemical effects of compounds

of carbon, nitrogen and sulfur released during coal combustion dominate environmental studies and debates, releases of other constituents such as arsenic, mercury, lead and similar toxins, along with radioactive materials and nuclear fuels, constitute additional topics of interest. Many indicators; suggest that trends in fossil fuel consumption are at odds with the purpose of these laws and their philosophies of supporting ecologically sustainable technologies for the future.

Background

Elemental analysis of coal from around the world reveals that it can be composed of as many as 73 elements[6]. When coal is mined and burned, these long buried elements are released directly into the biosphere. As combustion increases, the quantities of these elements increase in direct proportion. While concerns about fossil fuel combustion has centered primarily on carbon, sulfur and nitrogen compounds, the quantities of radiological and toxicological components are not trivial and are among topics discussed herein.

For example, 1991 global coal production was 5,100 million tons, up 50% from 1973, and continues to rise. US production that year was 996 million tons[7]. Analysis of coal reveals significant quantities of radioactive species, including uranium and thorium, that are long-lived parents in natural radioactive decay chains. Coal also contains potassium-40, and each radionuclide in coal accumulates in the atmosphere as a result of combustion. According to International Atomic Energy

Agency (IAEA) data[8], coal contains an average of about 2.08 parts per million (ppm) of uranium, 4.58 ppm thorium and 0.054 ppm potassium-40. Although small concentrations, these components are significant when the vast quantity of coal mined and burned is considered, and more so when collected over a long period of time[9].

Radioactive material flowing from a coal fired utility is a function of the quantity of material originally in the coal. Analysis of US coal samples shows that many deposits contain far higher concentrations than IAEA average values. For example, J. F. Facer showed in a 1979 US Dept. of Energy (DOE) report that some US coal contains in excess of 103 parts per million of uranium[10]. Consequently, deposits of coal with this concentration release more than 200 tons of uranium per 1000 N We/year compared to approximately 8 tons/year using IAEA average value data. However, the USEPA concluded in its 1984 report, "Background Information Document (Integrated Risk Assessment); Final Rule for Radionuclides", that coal wastes constitute no significant integrated risk[l1]. Extensive studies, such as the report by Beck et al[12] in 1980, "Perturbations on the Natural Radiation Environment Due to the Utilization of Coal as an Energy Source," provided analytical data supporting the EPA position.

In addition to radiological material, elemental analysis of coal for other constituents illustrates that it is a rich source of valuable metals. Table 1 is a summary of 40 elements giving estimated values for annual US utility combustion. While the Resource Conservation and

Recovery Act (RCRA) addresses issues of conserving natural resources, the vast quantities of mineral wealth in coal are rarely addressed. Coal "wastes" are not considered "resources".

Consequences

The influence of current environmental, energy and resource conservation laws have little effect on preventing the accumulation of the vast array of coal-borne material in the biosphere. Quantities of by-products released from coal combustion are sufficient to present environmental, resource, energy and economic issues. For example, using 1991 production figures cited above and assuming that all the coal mined that year was burned somewhere, IAEA average concentration data indicates that at least 10,600 tons of uranium, 23,400 tons of thorium, and 275 tons of K-40 were released into the global biosphere that year alone. Summing over a century spanning 1937 to 2037, a length of time that places us currently at more than 60% through, indicates that in the US, as much as 232,400 tons of uranium, 572,000 tons of thorium and 6,030 tons of K-40 will be introduced into the biosphere during that time, mostly during the latter half. Global accumulation of these long-lived radioactive species is predicted to exceed 1 million tons of uranium, 2.8 million tons of thorium and more than 30,000 tons of K-40 by the year 2037.

Natural uranium contains fissionable isotope U-235 at about 0.7%. U-235 is the nuclear fuel in commercial reactors. Release of U-235 into the biosphere over the specified century totals more than 9,400 tons of this single isotope. As 2% enriched commercial reactor fuel, this quantity of U-235 equals more than 471,000 tons of nuclear fuel, the equivalent of 15,700 reactor loads of 30 tons each. Consequently, the fissile component of the uranium in coal constitutes an enormous quantity of resource energy that is never recognized as a hazard nor utilized as a fuel. Comparing energy values, this amount of U-235 when fissioned equals more than 4.6 billion tons of coal, worth about $78 billion. This wasted energy is the result of selectively ignoring the potential resources of coal. Further, this quantity of fissile material poses nuclear proliferation issues because the material is within the boundaries of any country with coal sources and combustion facilities.

Like the more common isotope U-238, thorium-232 is non-fissile but is breedable to produce fissionable nuclear fuel as isotope U-233. This process can occur in nuclear reactors and involves addition of a neutron to the nucleus of a non-fissile isotope that then becomes fissile. Because the ratio of combustion-to-fissile energy is approximately 1:5million per unit of matter, the fission energy contained in the quantities of these isotopes of uranium and thorium exceed the energy value of the coal itself and indicate that vast quantities of energy are routinely wasted with coal combustion.

The radioisotopes in coal constitute a continuing source of radioactive released into the biosphere. Estimates of average contributions total about 4.3 micro-Curies per ton[13]. Thus, combustion of 5,100 million tons of coal in 1991 released about 22,000 Curies of radioactivity that year alone. Since one Curie equals 3.7 x 10^{10} nuclear disintegrations each second, this quantity of radioactivity is quite large. Integrated over the century in question, coal combustion is predicted to release at least 480,000 Ci of radioactivity in the US and more than 2.7 million Curies world-wide by the year 2037.

Table 2 summaries a US Dept.. of Commerce study conducted in 1975 that compared stack emissions from three types of coal fired utilities[14]. Exhausted fly ash ranged from 2.9 million lbs/year from the electrostatic precipitator station studied to 97 million lbs/year from a cyclone type plant burning lignite coal. Most US power plants are modern with facilities to minimize release of fly ash However, over time, increasing quantities of lignite are predicted to be burned due to reduction in reserves of higher grade coal. Lignite is a high moisture soft coal with constituent concentrations far exceeding higher grades at less than half the energy content.

Modern electrostatic precipitator plants are capable of operating at greater than 99.5% collection efficiency but can still release 35 lb/year of uranium as just one component in almost 3 million tons of ash vented through stacks. In addition to this radiological species, all the radon in coal is released during combustion. An estimate for average Rn-222 release is about 2 Curies/year for each 1000 MWe coal fired facility[15]. Though much larger in total quantity, Radon-220 from the Thorium chain has a half-life of 55 seconds and may not make it out of the stack. Materials of all types not exhausted up the stack are collected in ash ponds and waste areas at the facility.

Coal fired electric power utilities are generally in close proximity to large population centers. Thus, exposures to the surrounding populace can be far higher than from equivalent nuclear power plants, by a factor of 100 as shown in one study[16]. The quantity of coal required to produce 1000 MWe, about 4 million tons each year, contains about 0.22 tons of the radioisotope K-40. Integrating over the century between 1937 and 2037 indicates that millions of Curies of long-lived radioactive isotopes in the uranium and thorium series, along with potassium-40, will be added to the biosphere by the later date. Quantities of radiological species released beyond the year 2037 are bounded only by the quantity of coal burned.

Most of the exposure to human beings from natural radioactivity is caused by the mobility of radon. Radon found in the atmosphere is produced largely from the uranium-238 series (Fig. 3) as radioisotope Rn-222. The effects of radon are said to range from insignificant (Beck, et al. Ref. 12) to significant. Bernard Cohen at the University of Pittsburgh compares coal power with nuclear power saying, "If one considers the very long-term effects of radiotoxicity, coal burning is a major killer and nuclear power is a major lifesaver."[16]

Because radon isotopes result from radioactive decay of uranium and thorium, the quantity of radon in the atmosphere increases with increased combustion. One consequence of radon in the biosphere is the increase of radioactive daughters such as those detected in consumer products. For example, radon decay radioisotopes of bismuth, lead and polonium have been detected in tobacco smoke. The dose rate to smokers produced by this radioactivity has been estimated for 1 .5 pack/day cigarette smokers to range from 1,300 milli-rem/year to 16,000 milli-rem/year[17]. The first figure is almost 4 times greater than the total whole body dose rate from natural background radiation. The latter figure is over 44 times greater.

For comparison, the maximum exposure from ionizing radiation for nuclear industry workers permitted by DOE guidelines is 5000 mill-rem/year. Current nuclear industry guidelines using the philosophy of "As Low As Reasonably Achievable" (ALARA) have targeted no more than 500 milli-rem/year dose rate per worker. Thus, the 1.5 pack/day smokers among the approximately 50 million smokers in the US willingly expose sensitive portions of their bodies to at least 2.6 times ALARA goals and perhaps 32 times the exposure permitted nuclear industry workers.

Table 3 illustrates the naturally occurring radioactive decay chains of uranium and thorium. The quantities of each isotope at any time are functions of original quantities and time since release. Note that radiotoxicity is, generally, associated with half-life. The shorter the half-life, the higher the radiotoxicity. For example, radium-224 originating in the thorium chain is more radiotoxic than radium-226 originating in the thorium-238 chain, and both isotopes are more radiotoxic than plutonium-239. Even though more radiotoxic than plutonium, note that EPA's assessments of the radiological aspects of coal combustion have concluded that health risks are minimal.

More Considerations

Not only does coal contain vast quantities of untapped energy, It also contains similarly vast quantities of useful metals. IAEA data lists aluminum concentration in coal at 26,400 ppm. Thus, worldwide flow of aluminum with the coal produced in 1991 was more than 136.6 million tons that year alone. Magnesium? At 3,419 ppm, in excess of 17.4 million tons of this metal were also in the coal flow streams that year, along with 6.3 million tons of titanium (1,242 ppm), 232,000 tons of vanadium (45.5 ppm) and other useful elements that were simply exhausted as coal waste, whether useful or harmful.

The latter group includes arsenic, cadmium, mercury, selenium, zinc and other elements in a variety of molecular forms. Based on lAEA data, global additions of these elements via coal combustion during 1991 were 25,500 tons of arsenic, 2,040 tons of cadmium, more than 5,000 tons of mercury, 23,200 tons of selenium, 34,700 tons of zinc and so on for each element in coal.

Adding release quantities for 100 years of steadily increasing coal combustion indicates that a broad range of exhaust constituents go well beyond atmospheric warming, acid rain and ozone depletion, such as the addition of 3.2 million tons of arsenic predicted to be added to the biosphere during that time.

Conflicting Policy

Application of RCRA law to conserve resources also reduces environmental impact by recovering the mineral wealth in coal. In doing so, nuclear issues become a major concern. However, our current policy of selective ignorance allows diffusion of millions of tons of radiological and toxicological material into the biosphere and places application of RCRA,, environmental and energy conservation laws at odds with public interests.

Since global population growth and energy use trends are easily predictable, the trends outlined herein illustrate expectations for our nuclear future. Modern civilization is powering itself with increasing quantities of coal. By removing coal from the earth's shielding overburden followed by combustion, all constituents are released in a vast range of forms. Biospheric effects increase in proportion to quantities of coal mined and burned.

This analysis indicates that the current regulatory framework does not apply to coal as it does to many industries, including nuclear power. Policy conflicts allow coal fired utilities to freely exhaust radiological material that nuclear utilities are closely regulated to prevent. Radiological material released from coal and nuclear utilities of comparable electrical output are such that public outcry against any nuclear utility releasing 27 tons of nuclear material each year would be enormous, yet coal borne releases of this material continue unabated. Even though extensive scientific evidence indicates that coal contains significant quantities of material with a broad range of consequences, little interest or concern is expressed by the public, most likely because coal is so familiar and so easily accessible.

Conclusions

The first conclusion to be drawn is that coal combustion wastes more energy than it produces. Another conclusion is that exposure from coal-borne nuclear material in the biosphere may exceed equivalent nuclear power facilities by a factor of 100. A third is that radioactivity in the biosphere is increasing proportionate to the quantity of coal burned, but may be insignificant in terms of integrated risk. A fourth is that coal combustion releases massive quantities of toxic substances. A fifth is that coal combustion can contribute to nuclear proliferation. The latter conclusion is more pronounced when the range of concentration is recognized. Coal that is significantly richer in uranium and thorium than global average figures poses greater proliferation concerns.

A sixth conclusion drawn from the untapped mineral wealth in coal further illustrates the effects of selective ignorance. RCRA law was enacted to conserve and recover useful minerals, yet the vast quantities of resources available in coal ash go unutilized. However, if RCRA law is applied to coal combustion, new technologies are required for mineral recovery that will lead to successively higher concentrations of residual nuclear material, thus producing nuclear proliferation concerns. A paradox is revealed, current law selectively ignores major issues of public concern while concentrating on others in the quest for zero environmental impact, yet application of the laws for mineral reclamation from coal results in collection of large quantities of radiological and nuclear material.

Consequently, addressing issues of coal and it's wastes requires addressing nuclear issues as well. However, selective ignorance may, in fact, be conscious avoidance of nuclear issues associated with coal by maintaining a policy of "dilution is the solution to pollution". This policy is clearly evident in utility exhaust stacks that have been increased in height to distribute exhausts over broader expanses of the earth's surface. Thus diluted, effects of the exhausts are diminished while all resources in the exhausts are thereafter lost to recovery.

In economic terms, studies of metal oxide recovery from fly ash indicate that current technology is sufficiently developed to give a return on investment capital in excess of 25%[18], yet no such initiative has been forthcoming. While it may be useful to implement strategies to recover metals from coal, and to isolate greenhouse gases and toxic materials, these same strategies must also address the accumulation of substantial quantities of nuclear material. Bounded only by dispersion in the dilution case and accumulation in the reduction case, recoverable quantities of nuclear material in coal force a serious rethinking of coal-based economies.

Toward a Desirable Future

In terms of securing a desirable future free of continual releases of elements contained in coal, while still providing the energy needs of expanding industrialization, new technologies are needed to trap coal combustion by-products. These new technologies maintain the current pro-fossil fuel policy by focusing utilization strategies on all constituents in coal, not simply its heat content alone. These new technologies can secure an economic and environmental advantage by fully utilizing coal through application of scientific methods to extract elemental forms at some point during the pre-combustion, combustion or post-combustion phases, thus preventing their release to the biosphere. further, utilization of the nuclear energy in coal extends earth's energy supply from coal by at least a factor of two.

The need for application of basic scientific research to develop new technologies to meet national priorities set in RCRA, environmental and energy conservation law has been illustrated. However, in doing so a range of nuclear issues become a consequence. To enact and utilize all of the mineral and energy wealth in coal reduces many environmental and ecological concerns and opens vast opportunities while embracing nuclear power and its wastes as the terminus. By collecting nuclear fuels from coal, vast quantities of energy are accumulated. Since current policy is based on low integrated risk of coal-borne effluents, diffusion of coal's components into the biosphere continues unabated. As nuclear power plants age, replacing many of them with fossil fuel plants is expected, and additions of new base load power world NWe are predicted to continue to be fossil fuel for the foreseeable future with the purpose of environmental sustainability in mind, application of science to improved utilization of the total resource value of coal establishes a range of missions for the world's scientific community.

Future Vision

This evaluation indicates that coal is an extremely valuable resource with vast untapped potential. After assessing its composition and the broad range of effects resulting from combustion, the rationale of current energy policy comes into question when long range effects and loss of resources is considered. Far-reaching strategies to maximize the great resource potential of coal offers many favorable options for a desirable future.

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