A RELATIVE RISK ESTIMATION OF EXCESSIVE FREQUENCY OF MALIGNANT TUMORS IN POPULATION DUE TO DISCHARGES INTO THE ATMOSPHERE FROM FOSSIL-FUEL AND NUCLEAR POWER STATIONS

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The leading role in environmental pollution belongs to the production of electrical and thermal energy.

Recently there appeared a number of papers dealing with a relative estimation of detriment to the environment and human health due to discharges into the atmosphere from nuclear power stations (NPS) and power stations of traditional type using fossil-fuel (FFPS) (1-6). The estimation of detriment from FFPS is usually performed in these papers basing on the most important components of their discharges, i. e. fly ash, sulfur and nitrogen oxides. However, these papers do not allow one to compare discharges from NPS and FFPS according to similar and clear parameters of detriment since the only currently adopted possible effect of discharges into the atmosphere from NPS is potential risk of excessive frequency of cancer and genetic injury. In some papers and attempt has been made to compare discharges from FFPS and NPS according to adequate parameters, i. e. the degree of radiation exposure of population because discharges from FFPS contain natural radionuclides (2-6). These papers, however fail to consider the whole range of natural radionuclides, and to calculate radiation risk. All this makes comparison more difficult since discharges from FFPS and NPS result in irradiation of different organs and tissues which in addition have various radiosensitivity.

In our paper we made and attempt to estimate radiation risk due to all main natural radionuclides which are contained in discharges from FFPS and to determine risk due to chemical cancerogenic substances released from FFPS. The study was made on the base of the modern Kamensk-Dneprovsk state district power station (SDPS) whose power is 1.200 MW (e) and which operates on coal mined in the Donetz Basin. In addition we used some data obtained at studying the environment around the Shatursk SDPS and the Kokhtla-Yarve FFPS. Radiation exposure of population to gaseous-aerosol discharges of NPS is given from the literary data on water-cooled power reactors (7). It has been estimated that 1 g of fly ash from the Kamensk-Dneprovsk SDPS avaragely contains (pCi): radium-226 - 5.0, radium-228 - 3.1, thorium-232 - 5.0, potassium-40 - 50, plumbum-210 - 12.0, polonium-210 - 12.0. The coal content of radon-222 was from 0.3 to 2.0 pCi/g. The calculations were made with allowance for the effect of daughter radionuclides and the accumulation of radionuclides in the environment as a result of the power stations operating for the period of 20 years. Contamination of food products was estimated on the base of air and soil routes of intake. An estimation of radionuclide content in the human body was made by the ratio between radionuclide intake and its content in the given organ which is characteristic of the natural conditions. The accumulation factor of radium-228 is assumed two times less than that of radium-226. It was also assumed that when coal is being burned all radon which is contained in it was released to the atmosphere. Potassium-40 was considered only as a source of external irradiation (due to homeostatic mechanisms limiting natural potassium intake). Transfer of thorium-232 through the food chains was not considered because of its extremely low absorption from the gastrointestinal tract. At calculating doses to the surrounding population we assumed that all ash released from SDPS ($1.26 \cdot 10^5$ tons per year) is deposited in the range of 18 km from the station. Calculation of the risk of excessive deaths due to radiation exposure was made on the base of the linear "dose - effect" dependence (8).

The data on radiation exposure of the population in the USSR living near NPS are given in Table 1.

Critical organ	RADIATION DOSE DUE TO RADIONUCLIDE				
	^{137}Cs	^{90}Sr	^{131}I**	Inert radioactive gases**	$\sum$
The whole body	0.004	-	-	0.36	0.36
Bone tissue	-	0.29	-	-	0.29
Thyroid*	-	-	2.2	-	2.2
Bone marrow	-	0.02	-	-	0.02

* Dose to the infants younger than 1 year.
** Dose at the border of the sanitary-protective zone.

TABLE 1 Mean Individual Radiation Doses to Individuals From the Population of the USSR due to the Actual Radioactive Discharges From NPS in 1975 (mrem/year per 10^3 MW (e)

The data on radiation exposure of the population living near FFPS are given in Table 2.

The absorbed doses due to long-lived radionuclides given in Tables 1 and 2 result from the continuous 20-year-operation period of power stations. Comparative data on the radiation risk for the population living near power stations are given in Table 3.

The data of Table 3 indicate that the radiation risk to the population living near NPS (on condition of their normal operation) is about 30 times less than that to the population living near FFPS. This ratio is also valid for high-power boiling reactors though their discharges of ^{131}I are increas-

Critical organ	RADIATION DOSE DUE TO RADIONUCLIDE						
	^{226}Ra	^{228}Ra	^{210}Pb	^{210}Po	^{232}Th	^{40}K	$\sum$
Bone tissue	0.74	0.002	19.3	93.0	-	0.45	113.8
Bone marrow	0.05	$5 \cdot 10^{-4}$	1.9	13.1	-	0.45	14.5
Lungs	0.71	0.1	1.44	0.88	37.8	0.45	41.4
The whole body	-	-	-	-	-	0.53	0.53

TABLE 2 Mean Individual Radiation Doses to the Population Living near FFPS Operating on Cool (mrem/year per 10^3 MW (e)

CAUSE OF DEATH	FFPS	NPS
Leucosis	$4.4 \cdot 10^{-2}$	$5.5 \cdot 10^{-5}$
Bone tumors	$1.1 \cdot 10^{-2}$	$2.9 \cdot 10^{-5}$
Lung tumors	$1.7 \cdot 10^{-1}$	-
Various types of tumors due to whole body irradiation	$1.1 \cdot 10^{+2}$	$7.5 \cdot 10^{+3}$
Thyroid tumors*	-	$3.6 \cdot 10^{-5}$
All above causes	$2.4 \cdot 10^{-1}$	$7.6 \cdot 10^{-3}$

* With allowance for the dose distribution according to age.

TABLE 3 The Risk of Increased Mortality for the Population Living Near NPS and Coal FFPS From Malignant Neoplasms due to Irradiation (lethal cases per 10^5 population per year with the power of 10^3 MW (e)

ed risk of lung cancer which may be caused in the vicinity of FFPS by radionuclides penetrating the lungs with ashes. The dose to the lungs from fly ash is calculated on the assumption that 100% of the particles reach (due to high dispersion) lung alveoli. But the risk due to both the effect of radium-226, plumbum-210 and polonium-210 penetrating the body with food products and the irradiation of the whole body by potassium-40 accumulating on the soil is also increased near FFPS. It is to note that the absolute value of radiation risk (resulting from discharges) to the population living near power stations is not large in both cases. In the case of the population group of 10^5 persons living near FFPS it can be (theoretically) expected that about 15 additional death cases from cancer will occur during life of one generation (with the mortality level from spontaneous cancer during this time period being $1.5 \cdot 10^3$) (10), while in the case of the same population living near NPS not a single case of additional cancer is expected.

The corresponding calculations made for FFPS operating on black oil show that irradiation of bone tissue and bone marrow and lungs due to their discharges is 5 and 30 times less per power unit respectively than the corresponding values due to discharges from FFPS operating on coal.

It is known that not only radionuclides but also chemical substances contained in the discharges from FFPS may be cancerogenic. The most well known and active among the latter substances is 3,4-benzapyren (3,4-BP). We determined the content of this substance in fly ash released from FFPS of several types. Depending on the fuel type and the character of its burning the content of BP in ash ranged from 0.14 μg/kg (Donetz coal ash at the Kamensk-Dneprovsk SDPS) - 0.17 μg/kg (peaty ash from the Shatursk SDPS) to 1870 μg/kg (shale ash from the Kokhtla-Yarve FFPS). The greatest content of BP is observed when the fuel burning is not complete which is the case at less modern and low-powered FFPS. The estimated content of 3,4-BP (due to fly ash from FFPS) in the air of the Kokhtla-Yarve city calculated on the assumption that the dust content in the air of the city is at the level of maximum-permissible dust concentration (0.15 mg/m^3) and the possible risk of additional deaths from lung cancer determined from the study (11) are given below: concentration of 3,4-BP in the air due to fly ash from FFPS - 0.028 $\mu g/m^3$; risk of increased morbidity corresponding to the 3,4-BP concentration of 0.1 $\mu g/m^3$ (cases per year) - 13 per 10^5 of population; risk due to 3,4-BP content in the air - $3.6 \cdot 10^5$ of population; dose of lung irradiation which induces the risk equal to the risk from 3,4-BP in the discharges - 1 rem/year; actual lung cancer rate at Kokhtla-Yarve in 1970 (10) - 34 per 10^5 of population. The data on the risk from 3,4-BP should be regarded as tentative ones because data characterizing the "dose - effect" dependence of this substance are not available. These data are rather conventional but they make it possible to estimate that the risk due to 3,4-BP in discharges from FFPS is probably much more significant than the summary risk from all types of irradiation to which the population is subjected due to contamination of the environment by radionuclides. If the burning of coal is more complete as it is the case at modern FFPS the risk from 3,4-BP will be negligible. However, it should be noted that fly ash from coal FFPS contains iron oxides and oxides of other metals. Our experiments on mice with inhalation route of iron oxide intake (2.5 mg per mouse) showed that this substance could cause lung cancer in the majority of animals. Some data on high cancerogenic activity of nickel are available. Nickel as well as vanadium, silver, iron and other metals are contained in large quantities in ash of FFPS operating on black oil. In the ash of oil from different deposits there are from 2.5 to 36% of nickel and up to 74% of vanadium (12).

Conclusions

The risk of excessive deaths from malignant tumors in population living near NPS is practically negligible ($n \cdot 10^{-2}$ cases per year per 10^5 persons). This risk is about 30 times less than the risk from radionuclides contained in discharges from FFPS operating on coal.

Discharges from FFPS operating on coal and black oil contain metals and chemical cancerogenic substances causing additional risk which often significantly exceeds the risk from radioactive components of discharges.

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