OVERVIEW OF ENVIRONMENTAL ASSESSMENT FOR CHINA NUCLEAR POWER INDUSTRY AND COAL-FIRED POWER INDUSTRY

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ABSTRACT

A quantitative environmental assessment method and the corresponding computer code are introduced in this paper. By the consideration of all fuel cycle steps, it gives that the public health risk of China nuclear power industry is 5.2×10^{-1} man /(GW·a), the occupational health risk is 2.5 man /(GW·a), and the total health risk is 3.0 man /(GW·a). After the health risk calculation for coal mining, transport, burning up and ash disposal, it gives that the public health risk of China coal-fired power industry is 3.6 man/(GW·a), the occupational health risk is 50 man /(GW·a), and the total is 54 man /(GW·a). Accordingly, the conclusion that China nuclear power industry is an industry with high safety and cleanness is derived at the end.

Keywords Environment assessment, Energy and environment, Nuclear power plant, Coal-fired power plant, Health risk

1 INTRODUCTION

From the view of health effects, a method and the corresponding computer package HLRISK are given to try to numerically evaluate the environmental impacts of radioactive, chemical carcinogenic and noncarcinogenic contaminants. In addition, the effects associated with the occupational injures are also delt with in this method. In calculation, the health risk resulted from accidents is divided into acute health risk category for both occupational workers and public, the health risk for public and occupational workers due to the exposure to radioactive, chemical contaminants into other category: chronic health risk. So the health risks may be answered in detail.

Four major pathways of radioactive and chemical contaminants migration are considered in this package to evaluate the chronic health risk: atmospheric, non-tidal rivers, coastal regions and groundwater.

2 METHODS AND CALCULATION

2.1 Atmospheric pathway

A standard straight-line, sector-averaged Gaussian model is selected as the basis of the atmospheric pathway model. In calculation, the fate of contaminants' concentration

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due to dry and wet deposition, radioactive decay, and chemical reaction are accounted. For chemical reaction that are fast enough to significantly change the air-borne concentration within the plume is calculated by using first-order degradation coefficient. Three kinds of release model and two kinds of plume rise mechanism are considered. The ground surface roughness between the release point and the assessment point may also be considered. In addition, if necessary, the local atmospheric circulation and stagnation correction factors are used to correct the plume dispersion, the building wake effects may be corrected for ground release model.

2.2 Non-tidal rivers

For the dispersion of contaminants in non-tidal rivers, the flow is assumed to be unidirectional and approximately steady. The two-dimensional steady state advective-dispersive equation is applied. In calculation the vertical variation of velocity and concentration are neglected, and the mechanism of advection and dispersion is just considered. The concentration reduction is calculated by using radioactive decay constants for the radionuclides and the first-order degradation coefficient for chemical contaminants respectively.

2.3 Coastal regions

Because the dilution of contaminants in ocean is strongly controlled by multiharmonic tidal phenomena, the three-dimensional transient, advective-dispersive equation, mass, momentum, and heat conservation equation are used. Then the contaminants are assumed to be conservative, the processes associated with reaction, decay, adsorption desorption between the water column and suspended or bed sediments are not addressed.

2.4 Groundwater

In unsaturated groundwater medium, the water flow is assumed to be unidirectional, the one-dimensional advective-dispersive equation is used. The three-dimensional advective-dispersive equation is applied to simulate contaminants' migration in saturated groundwater aquifer. The analytical solution is found by assuming that all aquifer properties are homogeneous and isotropic in unsaturated or saturated zones.

2.5 Methods of health risk calculation

By above predictions of contaminants dispersion, and by the parameters about contaminants' bio-accumulation and transfer through aquatic and terrestrial food and animal product chains, the calculation of collective effective doses for radionuclides and average daily intakes per unit of body weight for chemicals are performed. Then the associated health risk are calculated as follows[1]:

2.5.1 Radionuclides

The individual health risk R(dimensionless) due to radiation is:

$$R = rH_{\mathrm{E}}$$

where H_{E} is the individual effective dose (Sv), r is the radiaition risk factor (1/Sv), it is the health risk for 1 Sv effective dose. The value of $7.3 \times 10^{-2}\,\mathrm{Sv}^{-1}$ is given by ICRP-

Report 60, in which the risk of developing a fatal cancer is $5.0\times10^{-2}Sv^{-1}$, developing a nonfatal cancer is $1.0\times10^{-2}Sv^{-1}$, and the risk of developing a severe hereditary effect is $1.3\times10^{-2}Sv^{-1}$.

2.5.2 Carcinogenic chemicals

The R caused by exposure to a carcinogenic chemical is calculated by:

$$R = \sum_j (1 - e^{-D_j \cdot q_j})$$

where D_j is the average daily intake per unit body weight through j pathway (inhalation or ingestion, mg/(kg·d), q_j is the carcinogenic potency factor (CPF) of j exposure pathway $(\text{mg}/(\text{kg}\cdot\text{d}))^{-1}$, it is the risk of developing cancer for one unit average daily intake per unit body weight.

2.5.3 Non-carcinogenic chemicals

The R_j associated with exposure to a non-carcinogenic chemical through j exposure pathway is given by:

$$R_j = (D_j/RfD_j) \times 10^{-6}$$

where RfD_j is the reference dose for j exposure pathway (mg/(kg·d)). The individual health risk for exposure to non-carcinogenic chemicals at RfD level is assumed to be 10^{-6}[2].

The health risk for a group is derived by multiplying the individual health risk R by the pupulation.

Then this package is applied to calculate the environmental impacts of China nuclear power industry (CNPI) and China coal-fired power industry (CCPI). For CNPI, the public health risk due to the operation of Daya nuclear power plant (DYP) and Qinshan nuclear power plant (QSP) are calculated. Combining the reported health risk caused by uranium mining, milling, fuel element manufacturing, transport, the reprocessing of fuel and the final waste disposal[3], it gives that the public health risk of CNPI is 5.2×10^{-1} man/(GW·a), the occupational health risks is 2.5 man/(GW·a), and the total is about 3.0 man/(GW·a)[4].

2.6 Coal-fired power industry

In order to evaluate the environmental impacts of CCPI, two typical large capacity power plants of Douhe No.2 power plant (DHP, 2×600 MW) and Dalateqi power plant (DQP, 2×300 MW) are selected to calculate the health impacts due to plant operation. Then combining the researched health risk caused by coal mining and transport, it approximately gives that the public health risk of CCPI is 3.6 man/(GW·a), the occupational health risk is 50 man/(GW·a), and the total is about 54 man/(GW·a).

3 RESULTS AND DISCUSSION

The main results of calculation are presented in Tables 1 and 2. As just concern to dealth (the fatal cancer is treated as death), the following results can be drawn.

3.1 The health risk by nuclear power plant normal operation is just 1.8×10^{-2} man /(GW·a), makes up 0.6 % of the total; the risk due to uranium mining and milling is as high as to 3.5 man /(GW·a), amounts most of the total; the risk due to fuel element manufacturing is 2.2×10^{-2} man/(GW·a), accounts for 0.7 % of the total; the isotope seperating is 2.3×10^{-3} man /(GW·a), 0.1 % of the total; fuel reprocessing makes 1.3×10^{-3} man/(GW·a), 0.1 % of the total; fuel transport makes 1.7×10^{-2} man/(GW·a), 0.6 % of the total. The order of health risk from high to low is uranium mining and milling, fuel element manufacturing, reactor normal operation, fuel transport, isotope seperating and fuel reprocessing.

Table 1

The health risk of CNPI man/(GW·a)

Health risk	Acute health risk		Chronic health risk	
	Death	Injures	Fatal cancer	Others*
Uranium mining and milling	2.5	7.5×10^{-1}	4.7×10^{-1}	2.2×10^{-1}
Fuel element manufacturing	–	–	2.2×10^{-2}	1.0×10^{-2}
Isotope seperation	–	–	2.3×10^{-3}	1.0×10^{-3}
Fuel reprocessing	–	–	1.3×10^{-3}	6.0×10^{-4}
Fuel transport	1.0×10^{-2}	1.0×10^{-1}	7.1×10^{-3}	3.3×10^{-3}
Reactor normal operation	–	–	1.8×10^{-2}	8.3×10^{-3}
Reactor accidents	3.0×10^{-5}	2.0×10^{-3}	7.0×10^{-4}	7.1×10^{-3}
Total	2.5	8.5×10^{-1}	5.2×10^{-1}	2.5×10^{-1}

Note: * including the happening of nonfatal cancer and hereditary effect.

Table 2

The health risk of CCPI man/(GW·a)

Health risk	Acute health risk		Chronic health risk	
	Death	Injures	Fat. can.	Others*
Coal mining	48	34	–	–
Plant operation	2.2	5.7	3.2	5.9
Coal transport	9.1×10^{-1}	–	–	–
Total	51	39	3.2	5.9

Note: * including the radiation induced nonfatal cancer and the hereditary effect, and the effects by noncarcinogenic chemicals.

3.2 About the long term environmental impacts by CNPI's radioactive wastes, the migration calculation of contaminants leak from planned DYP and assumed QSP medium and low level radwaste disposal sites shows that, because of the absorption and retardation, there are very little amount of contaminants, which may migrate into surface water body, they almost do not induce harm to human health. By analysis of the researches abroad, it is roughly thought that the health risk caused by CNPI high level radwastes disposal is approximately 2.5 man/(GW·a) in the period of 1,000,000 a.

3.3 The health risk due to the contaminants release from coal-fired power plant is 3.2 man /(GW·a), makes up 5.9 % of the total; the plant operation accidents cause 2.2 man /(GW·a), amount to 4.1 % of the total; the health risk related to coal mining is as high as to 48 man /(GW·a), 89 % of the total; while the coal transport makes 9.1×10^{-1} man /(GW·a), 1.7 % of the total.

3.4 In the health risk due to coal-fired power plant emissions, it is found that the risk caused by non-active chemicals are much higher than that of radioactive materials, lead to 3.1 man/(GW·a), 15 times as much as that of radioactive emissions. And, in carcinogenic chemicals, Cr and As are most important, with causing the health risk of 1.6 and 1.2 man/(GW·a) respectively.

4 CONCLUSIONS

Combining above results, there are the quantitative environmental impacts' comparisons between CNPI and CCPI:

4.1 As to the acute health risk caused by accidents injures, CCPI may be as high as to 51 man /(GW·a), 20 times as much as that of CNPI. Detail comparisons give that, for occupational workers, CCPI produces 50 man /(GW·a), 20 times as much as that of CNPI; for public, CCPI makes 4.4×10^{-1} man /(GW·a), 40 times as much as that of CNPI.

4.2 As to chronic health risk caused by exposure to contaminants, CNPI produces 5.2×10^{-1} man /(GW·a), whereas it is as high as to 3.2 man /(GW·a), 6 times as much as that of CNPI, for CCPI within just accounted in the emissions from coal-fired power plant.

4.3 From the view of long-term environmental effects, the impacts caused by ash pond of CCPI are also severer than that by high, medium and low level radioactive waste disposal sites of CNPI. They are 13 man/(GW·a) in the period of 5,000 a and 2.5 man/(GW·a) in the period of 1,000,000 a respectively.

Accordingly, from the aspects of health effects, the conclusion that the impacts caused by CCPI are much higher than that of CNPI is derived. Therefore, CNPI is an industry with high safety and cleanness.

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