ASSESSMENT OF THE RADIATION EXPOSURE FROM THE RADIOACTIVE MATERIAL RELEASED FROM THE STACK OF A 2000 MWe COAL FIRED POWER STATION

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INTRODUCTION

This paper is a summary of work which is in progress at the National Radiological Protection Board to estimate the radiological impact of the discharges to atmosphere from a reference 2000 MWe coal fired power station. Provisional estimates are made of individual committed effective dose equivalents for members of hypothetical critical groups in the population whose habits would result in higher than average radiation exposures, and the collective effective dose equivalent commitment to the population of Great Britain. The reduction in the natural background dose from ^{14}C resulting from releases of stable carbon is considered and finally, areas of further research relating to radiation exposure from the operation of coal fired power stations are identified.

SOURCE TERMS FOR DISCHARGE TO ATMOSPHERE

The activity discharged from the power station is in two phases: a gaseous phase consisting predominantly of radon gas and a solid particulate or ash phase containing ^{232}Th, ^{235}U, ^{238}U, ^{40}K and their chain decay products. The doses from radon discharges are insignificant (less than 0.2% of the total) and are not discussed further in this paper.

To calculate the release rate of radioactivity, the mass discharge rate of ash and the concentration of activity in ash are required. It is assumed that on full load the power station discharges at the Statutory Limit for particulate emission in the UK for modern power stations of 115 mg m^{-3}. With a load factor of 56%, this is equivalent to a discharge of $3.9\ 10^3$ t y^{-1} for a 2000 MWe power station (1). Data on the concentration of radioactivity in fly ash in the UK are limited and until further experimental measurements are reported an interim cautious estimate of 500 Bq kg^{-1} is used for each of the nuclides ^{232}Th, ^{238}U, ^{40}K and their chain decay products assuming equilibrium. It is recognised that this value may overestimate the concentration of non-volatile species in the decay chains and therefore the sensitivity of the results to this parameter is discussed later. Assuming a natural abundance of ^{235}U in uranium of 0.72% by mass, the concentration of ^{235}U in fly ash is taken to be 20 Bq kg^{-1}. A summary of the source terms for discharge is given in Table 1. The power station is assumed to discharge continuously at this rate during an operational life of 30 years.

TABLE 1. SOURCE TERMS FOR DISCHARGE TO ATMOSPHERE

	Discharge rate ($Bq\ y^{-1}$)
^{235}U series	$7.8\ 10^{7}$
^{232}Th series	$2.0\ 10^{9}$
^{238}U series	$2.0\ 10^{9}$
^{40}K	$2.0\ 10^{9}$
^{14}C*	$-9.0\ 10^{11}$

* See text for further explanation

ENVIRONMENTAL TRANSFER AND PATHWAYS ANALYSIS

The environmental transfer models used in this assessment are based on a methodology to evaluate the consequences of routine radioactive releases developed by the National Radiological Protection Board in conjunction with the Comissariat a L'Energie Atomique (2) which was outlined in a previous paper at this Congress (3).

From the source terms, annual average concentrations in air and deposition rates to ground are predicted assuming a uniform wind rose and an effective release height of 500 m in Pasquill dispersion conditions A,B,C and D and taking into account wet and dry deposition. In EF weather, the effective release height is assumed to be at the inversion lid, 200m above ground level. The sensitivity of the results to the choice of stack height has been investigated for release heights of 400 and 600m and the results are found to vary by less than 5%. Three sites in different geographical locations in Great Britain were chosen for investigation (Midlands, Central Southern England and London), and meteorology characteristic of each of these sites was used. There is less than 10% variation in the collective doses from these sites. Intakes of radioactivity by ingestion and inhalation are converted to effective dose equivalents using the dosimetric data given by Adams et al (4).

Five pathways of exposure are considered : (i) External irradiation from the plume of activity - a 'finite cloud' model is used to calculate the dose rate in tissue 1m above ground level from photons originating in the plume. The maximum exposed individual is assumed to remain at the point of maximum average dose rate for a year. No allowance is made for shielding by buildings or clothing. (ii) Inhalation of the plume - the typical breathing rates for an average adult are used to calculate collective doses and those for an individual carrying out heavy work (5) to calculate doses to the maximum exposed individual. This individual is assumed to remain at the point of highest average air concentration for a year. (iii) External irradiation due to surface deposition - it is assumed that material deposited on the ground builds up during the operating life of the plant and that the external dose rate from a given deposit, calculated from a model of a uniformly contaminated plane, falls off exponentially with a 20y half-life. The maximum exposed individual is assumed to remain at the point of highest dose rate (which occurs in the 30th of operation) for a year. Again no allowance is made for possible shielding by buildings.

(iv) Resuspension of deposited activity - the model which is based on a resuspension factor approach, has two components, one of which represents resuspension from recent deposits weathering with a half-life of 55 days, the other from weathered deposits with a removal half-life of 100 years. The maximum exposed individual is assumed to breathe the highest resuspended air concentration. (v) Ingestion of contaminated foodstuffs - a dynamic compartment model is used to predict activity concentrations in plant and animal foodstuffs following transfer in the foodchains. The maximum exposed individual is assumed to ingest contaminated grain, green vegetables, root crops, meat, liver and milk at higher than average rates; these are taken to be 145, 80, 170, 90, 20 kg y^{-1} and 340 l y^{-1} respectively. These figures are consistent with values developed for assessing DL's for radioisotopes in the environment.

RELEASES OF STABLE CARBON

The specific activity of ^{14}C in exchangeable carbon in the biosphere is assumed to be reduced by releases of stable carbon from the power station. The carbon releases are equated with a negative discharge rate of ^{14}C as given in Table 1, and the dose reduction to individuals is estimated from carbon consumption rates of 300 kg y^{-1} and for the population from a per caput consumption rate of 93 kg y^{-1}.

TABLE 2. PROVISIONAL INDIVIDUAL AND COLLECTIVE DOSE ESTIMATES[a]

	Individual dose[b] (μSv)	Collective dose[c] (man-Sv)	Dominant radionuclides
External γ plume	$5.0\ 10^{-5}$	$7.9\ 10^{-3}$	^{214}Bi, ^{214}Pb
External γ ground	2.7	9.1	
Inhalation	1.1	$2.9\ 10^{2}$	^{232}Th, ^{230}Th, ^{228}Th
Resuspension	3.1	6.3	
Ingestion	$2.2\ 10^{2}$	$6.4\ 10^{1}$	^{210}Po, ^{210}Pb, ^{231}Pa
^{14}C	$-1.4\ 10^{-1}$	$-2.2\ 10^{1}$	-
Total	$2.3\ 10^{2}$(d)	$3.4\ 10^{2}$	^{232}Th, ^{210}Po, ^{230}Th, ^{210}Pb, ^{231}Pa, ^{228}Th

(a) Effective release height = 500m in ABCD weather : Site = South Oxfordshire : Site boundary = 400m
(b) Maximum annual committed effective dose equivalent to a hypothetical individual
(c) Collective effective dose equivalent commitment truncated to 500 years to the population of Great Britain from 30 years plant operation
(d) Total based on the cautious assumption that same hypothetical individual is exposed to the appropriate contribution from all these pathways at a distance of 400m from the stack

RESULTS AND DISCUSSION

The provisional individual and collective dose estimates are summarised in Table 2. The reduction in ^{14}C doses is significantly smaller than the dose from releases of fly ash. The annual committed effective dose equivalent to a hypothetical individual with habits characteristic of a critical group is 230 μSv and derives predominantly from ingestion of contaminated foodstuffs. The nuclides ^{210}Pb, ^{231}Pa and ^{210}Po give 43%, 38% and 14% of the maximum individual dose respectively. It should be noted that consistent overestimates of parameters are used in the models to predict the maximum individual dose, for example, in the assumption that the individual derives all components of his diet from the same location which corresponds to the point of maximum deposition . It is likely that, in practice the most exposed individual will receive a dose which is considerably smaller than the above estimate. The collective effective dose equivalent commitment to the population of Great Britain from the operation of the plant in South Oxfordshire for 30 years is 340 man-Sv. The pathways giving the highest collective dose are inhalation of the plume and ingestion of contaminated foodstuffs. The nuclides ^{232}Th, ^{210}Po, ^{230}Th and ^{228}Th give 49%, 10%, 10% and 9% of the collective dose from radioactive releases respectively.

The levels of dose calculated here indicate that further research should be devoted to improving understanding of the radiological impact from coal-fired power stations. Two of the subject areas to which this assessment is most sensitive are the transfer of Pb, Po and Pa into foodstuffs and the concentration of radioactivity in fly ash. For example, there is some evidence that activity concentrations of non volatile elements such as Ra and Th could be a factor of four lower than the values used in this study (6). If this is the case then collective doses would be reduced by up to a factor of three. Research effort should therefore initially be directed towards these subject areas. However this assessment only focusses on one aspect of part of the coal fuel cycle, and to put it into its true perspective the radiation exposure as a result of practices over the whole cycle should also be considered. Even these results would need to be looked at carefully within a wider context.

REFERENCES

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