INDIVIDUAL AND COLLECTIVE DOSES DUE TO ^{41}Ar BASED ON MEASURED DISCHARGE RATES FROM CEGB REACTORS

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ABSTRACT

Shield cooling air from early Magnox Reactors contains quantities of ^{41}Ar, a short-lived γ-emitter whose elevated release gives a finite exposure at the site boundaries. A series of experimental measurements has established the discharge rates of ^{41}Ar from the early CEGB reactors and the results have been used to estimate individual and collective doses around each site.

1. INTRODUCTION

In the early CEGB Magnox Reactors, which utilise steel pressure vessels, shield cooling air passes between the outside of the pressure vessel and the biological shield before being discharged to atmosphere. The stable isotope ^{40}Ar in that air becomes activated by neutron capture and the ^{41}Ar formed has a half-life of 1.83 hours and emits a 1.293MeV γ-ray in 99.2% of its decays. Because of the long mean free path of γ-rays in air, there are low, but not insignificant, dose rates at the site boundary. Measurements of ^{41}Ar discharge rates are not made routinely although one or two estimates have been given (1). In this paper, results are presented from experimental determinations of these discharge rates together with estimates of individual and collective dose distributions for each site.

2. EXPERIMENTAL MEASUREMENTS

Air samples were drawn from the shield cooling circuit at each station into a cylindrical vessel 200mm in diameter and 300mm high. The samples were normally taken at the base of the discharge stack and after the filters to ensure thorough mixing of air from different regions of the shield. After sufficient time to allow complete flushing of the vessel, it was sealed and removed for counting at a convenient location 2 - 8km from, and upwind of, the station to ensure the contribution of the station and the ^{41}Ar plume to the gamma background was negligible.

The detector consisted of a 75mm x 75mm NaI (Tl) crystal and the vessel located onto the detector head to ensure reproducibility. The system had been previously calibrated to relate activity density in the vessel to count rate in the 1.293MeV ^{41}Ar photopeak. Pulses from the detector were analysed by a multichannel analyser in 200 channels, each of width 10keV. Natural gamma background was accounted for by accumulating spectra with and without shield cooling air in the vessel and subtracting the background spectrum from the former.

The counts in the photopeak were summed, corrected for decay and the peak totals were related by the calibration factor to the activity density of ^{41}Ar at the time of collection. The discharge rate of ^{41}Ar was determined from the measured activity density and the shield cooling air volume flow rate. Table 1 gives the discharge rates at six stations.

The main source of error in the measurements is the uncertainty in the volume flow rate which may be in error by up to 10%. The statistical error in the count rate determinations was normally better than 1%. The

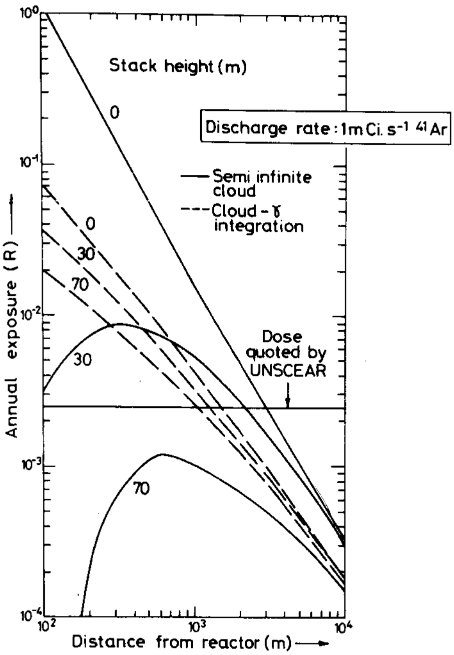

FIG.1. Annual Cloud - γ Exposure for a Release of 1m Ci. s^{-1} of ^{41}Ar, Calculated by the Semi-infinite Cloud Model and by Integration Over the Plume

Site	Reactor 1		Reactor 2		Mean Discharge Rate from Site 1 mCi s^{-1}
	Reactor Power MW (th)	Discharge Rate mCi s^{-1}	Reactor Power MW (th)	Discharge Rate mCi s^{-1}	
Berkeley	Not Measured 2		578	0.3	0.5
Bradwell	Only Station Figures Available				0.47
Hinkley Point A	890	1.4	924	1.6	2.3
Sizewell	610	0.9	785	1.0	2.0
Dungeness A	730	0.6	749	0.6	1.1
Trawsfynydd	825	2.7	812	2.6	4.8

1 Corrected for 1975 Station Load Factors

2 Reactor 1 Shut Down at Time of Measurements.

Table 1

Measured ^{41}Ar Discharge Rates and Corresponding Reactor Powers.

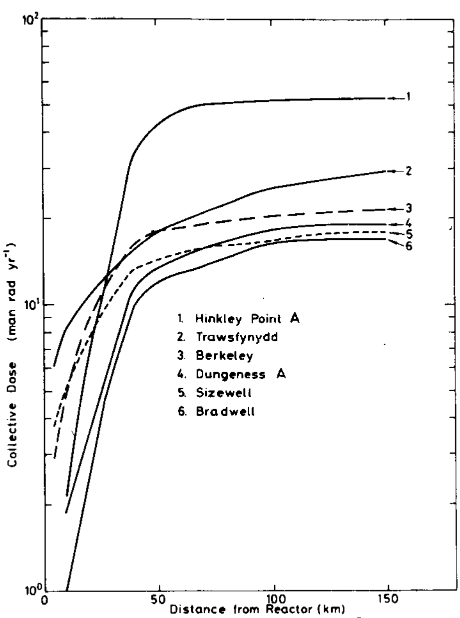

FIG.2. Collective Dose as a Function of Distance from Magnox Sites using Measured Discharge Rates of ^{41}Ar (Occupancy Screening and Load Factors Allowed)

Site	Frequency of Pasquill Category (%)							Mean Wind Speed m s^{-1}
	A	B	C	D	E	F	G	
Sizewell Dungeness	0	4	13	75	4	3	1	5.81
Trawsfynydd Bradwell Hinkley Pt.	1	5	15	65	6	6	2	5.14
Berkeley	1	6	17	60	7	7	2	4.47
Average UK Smith (4)	0.78	5.23	15.55	64.8	5.90	5.77	2.04	5.10
Bryant (5)	1.7	8.4	16.8	41.0	11.8	20.3	–	3.8

Table 2

Mean Frequencies of Occurence of Pasquill Weather Categories and Mean Windspeeds Around C E G B Magnox Sites and Averaged Over the U.K. Smith (4)

Continuous Meteorology Data	Annual Exposure at Site Boundary mR y^{-1} per mCi s^{-1}		
	100 m	200 m	400 m
Smith (4)	23.3	12.2	6.1
Bryant (5)	37.5	19.2	9.4

Table 3

Annual Cloud - γ Exposure for a Discharge Rate of 1 mCi s^{-1} ^{41}Ar from an Effective Stack Height of 30m Using Smith (4) and Bryant's (5) Data error in the calibration of the system was estimated to be ∿ 5%.

The calibration was carried out using a 1μCi ^{22}Na point source. ^{22}Na with a photon of energy 1.285MeV was used in preference to ^{41}Ar because of its longer half-life and easier handling. The counts in the photopeak were determined when the source was drawn vertically through the vessel at constant speed, at various radii. The count rate for a uniformly distributed source was then evaluated using numerical integration. Finally, a correction was made for the 8keV difference between the ^{22}Na and ^{41}Ar photon energies.

3. INDIVIDUAL DOSES AT THE SITE BOUNDARY

The computer code WEERIE (2) was used to calculate the ^{41}Ar cloud-γ exposure as a function of distance from the release point. The accuracy of the cloud-γ integration has been checked (3) against measured ^{41}Ar exposure rates measured around the early air-cooled graphite moderated reactors BEPO, Windscale and EL2. For the present work, the annual exposures were evaluated per unit release rate of ^{41}Ar at each site, assuming the mean frequency of occurence of the 7 Pasquill weather categories and associated windspeeds for a representative area up to about 100km from each site, which were taken from Meteorological Office Data (4) and are summarised in Table 2. Also shown in Table 2 are the average frequencies of weather categories given by Bryant (5) for the whole of the U.K. and those derived from Smith (4).

Assuming a 30m effective stack height, the cloud-γ exposures at a site boundary 100, 200 or 400m for a discharge rate of $1mCi.s^{-1}$ are shown in Table 3 for a uniform distribution of wind directions and taking Bryant's (5) or Smith's (4) average U.K. continuous release meteorological data. Clearly, Smith's data leads to significantly lower doses, partly due to the use of higher mean windspeeds.

UNSCEAR (6) in its review of radioactivity in the environment, calculated the exposure due to ^{41}Ar discharges at CEGB Magnox Reactors as $2.53mR.y^{-1}$ by using a continuous release dilution factor of 2.5×10^{-7} and the semi-infinite cloud model. In Figure 1 the annual exposure per unit release rate of ^{41}Ar for a variety of stack heights using the semi-infinite cloud model is compared with WEERIE cloud-γ integrations. The total inadequacy of the semi-infinite cloud model at short downwind distances is clear.

4. COLLECTIVE DOSE ESTIMATES

Methods of assessing Collective Doses for airborne effluents have been developed based upon integration spatial distribution of Dose over real population density matrices derived from census data (7). For the area around each site a representative table of wind direction frequencies was used to weight the WEERIE cloud-γ exposures. Since the WEERIE exposures are for whole body without any allowance for time spent indoors where there is a significant amount of shielding from the plume, an occupancy and screening factor was evaluated using the data of Healy (8). These data give screening factors of approximately 0.5 for downstairs in a brick house and 0.65 for upstairs. Assuming 33% of time spent upstairs, 50% downstairs and 17% effectively unshielded, an overall screening factor of 0.63 was used. Combining these results with those from Table 1, the estimated collective doses from CEGB Magnox Reactors as a function of distance are given in Figure 2.

5. CONCLUSIONS

Measured discharge rates of ^{41}Ar from CEGB Magnox sites are within the range of 0.5 to 4.8mCi.s^{-1}. The calculated individual doses at the site boundaries are in the range 10 to 120mR.yr^{-1}, which is significantly higher than that predicted by UNSCEAR. The associated collective doses have been estimated and range from less than 20 to 53 man-rad.yr^{-1}.

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