IN SITU MEASUREMENTS WITH A Ge(Li)-SPECTROMETER AROUND A NUCLEAR POWER STATION.

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1. INTRODUCTION

The development of large Ge(Li)-detectors with high energy resolution has not only made it possible to measure small amounts of artificial radionuclides in the natural radiation background but also offered a possibility to record very low exposure levels. Already in 1972 we started to build a mobile laboratory for Ge(Li)-spectrometry measurements in the field. This equipment was devoted to studies of the influence of nuclear power plants on the radiation field in their environment (1). Barsebäck Nuclear Power Station is situated about 17 km from Lund. This is a convenient distance for regular excursions from our Institute at the University. A network of measuring points was set up before the first reactor was started and the background levels were studied very carefully. After reactor startup in 1975 measurements have been performed at various distances from the reactor and at various occasions.

2. EQUIPMENT

Fig 1 shows the closed end coaxially drifted Ge(Li)-detector mounted on a tripod. The detector is set vertically beneath the cryostat in order to minimise shielding of the primary radiation field from ground deposited radionuclides. The preamplifier power is derived from NiCd-batteries with 8 h capacity. They are, however, normally charged from the generator. High voltage for the detector bias is obtained from an incapsulated battery package. As soon as the pulse height distribution is recorded in the analyzer core memory a preliminary evaluation is performed. Normally the data is transferred to paper tape for computer analysis at the laboratory in Lund. It is thus possible to calculate the amount of radionuclides deposited on ground in Bq/m^2 (nCi/m^2) and also to calculate the exposure contribution from each radionuclide in μR/h or absorbed dose rate in air μGy/s (μrad/h).

3. MEASUREMENTS

The background radiation field in the vicinity of Barsebäck Nuclear Power Plant was studied in 1974 when the plant was under construction. The reactor was started in Janury, 1975. No significant influence from the reactor operations was observed in measurements of ground activity concentrations carried out since the startup. Table 1 shows the results from measurements on a grass-covered area bordering the reactor fence line. The activity concentration of I-131 has been less than 7 Bq/m^2 (0.2 nCi/m^2) until October, 1976.

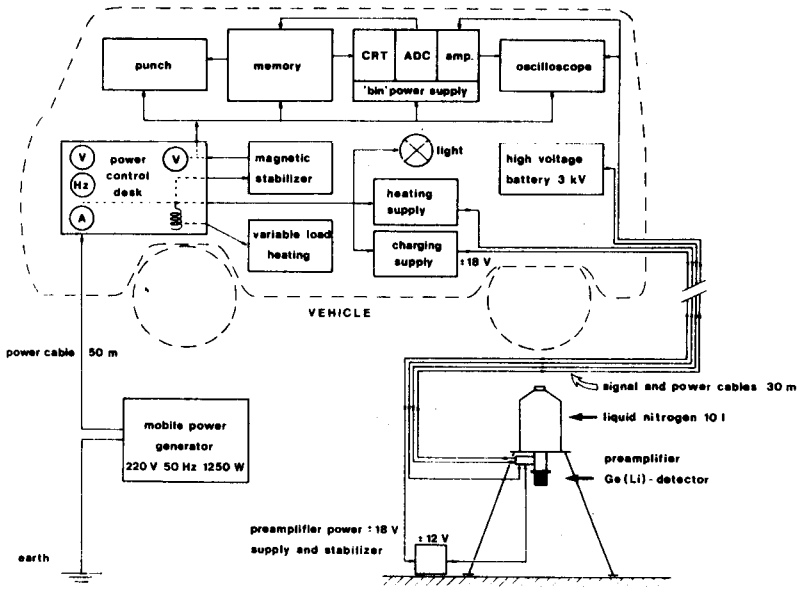

Fig 1. System diagram of field Ge(Li) gamma spectrometric equipment.

Year of measurement	Activity concentration, Bq/kg 238 U	232 Th	40 K	137 Cs
1974	14 ± 1	17 ± 1	555 ± 7	5.9 ± 0.4
1975	14 ± 1	17 ± 1	551 ± 7	5.9 ± 0.4
1976	13 ± 2	14 ± 2	518 ± 15	5.2 ± 0.7

TABLE 1 Activity concentrations in soil under a grass-covered area just outside the fence line of Barsebäck Nuclear Power Plant. The activity concentrations, including overall uncertainty limits, are given in Bq/kg (1 Bq = 0.027 nCi).

3.1 Fall-out Measurements

In measurements performed during the period October, 22 - November, 2 1976 fresh fission products were recorded at places in the vicinity of Barsebäck, Lund and Ljungbyhed (42 km north of Lund). The variation in surface area concentration of these fission products at the three places was very small. We therefore believe that they are originating from a Chinese nuclear explosion in the atmosphere of September, 26 1976. Fig 2 shows a pulse height distribution recorded in situ 1 m above ground at Barsebäck. Peaks in count rate due to natural radionuclides are indicated at the top of the figure and at the bottom are shown the fission products. Table 2 gives the area concentration of the main fission products recorded.

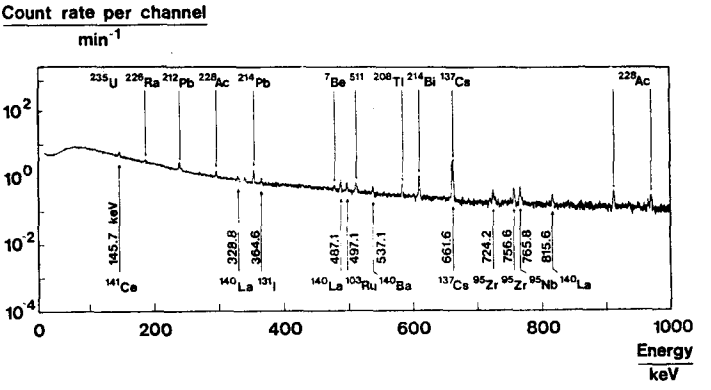

Fig 2. In situ pulse height distribution recorded at Barsebäck on 28 October 1976 with the Ge(Li) detector 1 m above ground. Counting time = 6 h.

	Bq/m ^{2}	nCi/m ^{2}
Ce-141	140 $^{+}_{-}$ 20	3,7 $^{+}_{-}$ 0,5
I-131	41 $^{+}_{-}$ 7	1,1 $^{+}_{-}$ 0,2
La-140	130 $^{+}_{-}$ 15	3,5 $^{+}_{-}$ 0,4
Ru-103	44 $^{+}_{-}$ 7	1,2 $^{+}_{-}$ 0,2
Zr-95	96 $^{+}_{-}$ 20	2,6 $^{+}_{-}$ 0,5
Nb-95	48 $^{+}_{-}$ 10	1,3 $^{+}_{-}$ 0,3

TABLE 2 Surface activity concentrations in Barsebäck 29 October 1976.

3.2 Radiation Field Measurements

Due to our carefully performed background studies before reactor startup we have been able to record an additional photon fluence near the power plant. A significant increase was detected in the 511 keV peak at 250 m from the reactor which was proportional to the power output of the generator. Further measurements revealed that this is due to N-16 ($T_{1/2}$ = 7.2 s) and C-15 ($T_{1/2}$ = 2.45 s) which are produced in the reactor water by the (n,p) and (n,α) reactions on O-16 and O-18 respectively. Scattered radiation from the high energy gamma rays of 5 - 7 MeV, produced in the decay of these radionuclides contributes significantly to the environmental radiation in the neighbourhood of a power station (2).

3.3 Measurements of Xe-133 Release

We have also recorded a test release of Xe-133 from the Barsebäck II reactor. The detector was placed at ground level in the direction of wind 200 m from the base of the 110 m release stack. A total activity of 260 GBq (7 Ci) was released through the stack during a time interval of 4.5 min. The detector recorded the full energy absorption peak at 81 keV and a large continuum of scattered radiation below this energy. From the measurements it was possible to estimate the minimum detectable release rate for Xe-133.

The minimum detectable release rates for Xe-133 at 110 m and wind speed of 6 m/s (lofting plume) are estimated to be about 30 MBq/s (0.8 mCi/s) assuming a continous release for a period of 1 hour and 10 MBq/s (0.3 mCi/s) during 6 hours release time. These values, however, depend directly on wind speed and are also sensitive to the shape and movement of the plume. The minimum detectable activity rates correspond to exposure rates at the detector of 0.05 μR/h and 0.02 μR/h respectively.

At this short distance from the release stack the geometry of the plume normally is quite simple and the distance to the ground is approximately equal to the stack height. At greater distances from the stack the shape and height of the plume depend very much on weather conditions and thus complicate the calculations of plume activity concentration. But a possibility exists to estimate an approximate effective distance to the plume from the ratio of count rate obtained in the full energy peak from primary photons to the count rate in the low energy continuum obtained from air-scattered photons. Normally, however, estimation of exposure rate at ground level is of the main interest. The direct calculation of exposure rates is done from measurements of primary and scattered radiation at the detector. This can be made more accurate than the activity calculations of the plume since no knowledge of source-detector distance is necessary in converting the pulse height distribution to exposure rate.

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