REPORT OF RADIONUCLIDES IN *AEDES COMMUNIS* PUPAE FROM CENTRAL SWEDEN, 1986

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Radioisotopes and ionizing radiation are well integrated components in the study and control of insect populations (IAEA 1982). Tracers have also been used to study the transfer of metals from sediment through Chironomidae to fish (Berg and Weiss 1975), or the cytogenetic effect of radioactive wastes in Chironomidae (Blaylock 1966), and for quantitative population studies (Nayar et al. 1979). However, studies of the influence of radioactive fallout on field populations do not exist for any aquatic insect larvae. Culicid larvae, feeding in temporary pools on microorganisms and possibly flocculate organic material, are dependent on atmospheric air for respiration and should be good indicators of fallout.

Radioactive substances from the Chernobyl (Ukraine) incident on April 26, 1986, were transported by weather systems and released as fallout over parts of Sweden including the Uppsala area (Fig. 1). During the weeks after the incident it rained quite heavily (Fig. 2), and thus temporary pools and ditches in a mixed forest belonging to Uppsala township were filled maximally with precipitation. After the sampling was finished the pools dried out very fast.

Aedes communis (De Geer) was the only mosquito species in the habitat and during late April and early May, mainly second and third instar larvae were present in the pool sampled. These were less than half the body size of the pupae sampled directly out of the same pool. Thus an important growth period lay between the fallout period (April 26–May 5) (Norman 1986) and the sampling of May 18, when the pupation period had begun two days before. Individuals which had not fed at least during a 24 hour period dominated this sample. Leaves and pine needles from the bottom of the pool were also sampled. Another sample of dry bottom material was also taken on August 19 and analyzed directly. During late August another heavy rain period started and precipitation again brought pools and ditches during September to full volume. Unhatched eggs of *Ae. communis* from the spring generation and/or newly laid eggs hatched in great numbers. New samples were taken during the end of September. Unfortunately a heavy evening frost killed the few larvae found in the original site. Therefore, the second sample of *Ae. communis* was taken from a nearby ditch (150 m), which was somewhat deeper and which contained sufficient numbers of larvae. These pupated in the same water after 5 days and were immediately frozen and stored for analysis. The analyses of the radionuclide were carried out by the Environmental Quality Laboratory at the Swedish Environmental Protection Board, Uppsala, using a GE (Li) Detector (EG & G Ortec) and MCA ND 66, 4096 channels.

The results of the sample analyses are summarized in Table 1. The presence of 10 radionuclides in the pupae was demonstrated in the May sample. The differences in concentration between radionuclides in pupae and the substrate indicated a selective uptake and excretion in feeding larvae to judge from the values obtained from the motile, but non-feeding pupae.

Three radionuclides were present in higher concentrations in the pupae than in the substrate: ^{131}I, ^{110m}Ag and ^{140}Ba. The values of ^{131}I (Table 1*) were calculated back to the sampling date. The high values of ^{131}I in the pupae indicate partly an accumulation via inhalation by the larvae during the fallout period. Later during the year no ^{131}I could be found. ^{134}Cs had no marked difference from the values in the substrate. All other radionuclides studied had a lower concentration in the pupae than in the substrate: ^{137}Cs somewhat lower, ^{103}Ru much lower, and ^{141}Ce, ^{144}Ce, ^{95}Zr, and ^{95}Nb very low. The relatively low concentrations of ^{95}Zr, ^{95}Nb, ^{141}Ce and ^{144}Ce in the organisms might, among other factors, also depend on the high proportion of particulate fractions in the fallout. These seemed to be less available for uptake by the larvae and pupae.

The benthic diatom *Melosira* was collected in the Uppsala area during the fallout period and showed high concentrations of various radionuclides (Table 1). It was added to indicate what values might be found in microorganisms during a fallout period.

The pupae from the October sample showed low values of ^{134}Cs and ^{137}Cs, the most long-lived radionuclides, as well as the presence of ^{110m}Ag and ^{60}Co. These two have been noticed in other Swedish studies, i.e., algae from the coast of the Baltic. They show that activation products were included in the Chernobyl fallout. Most of the

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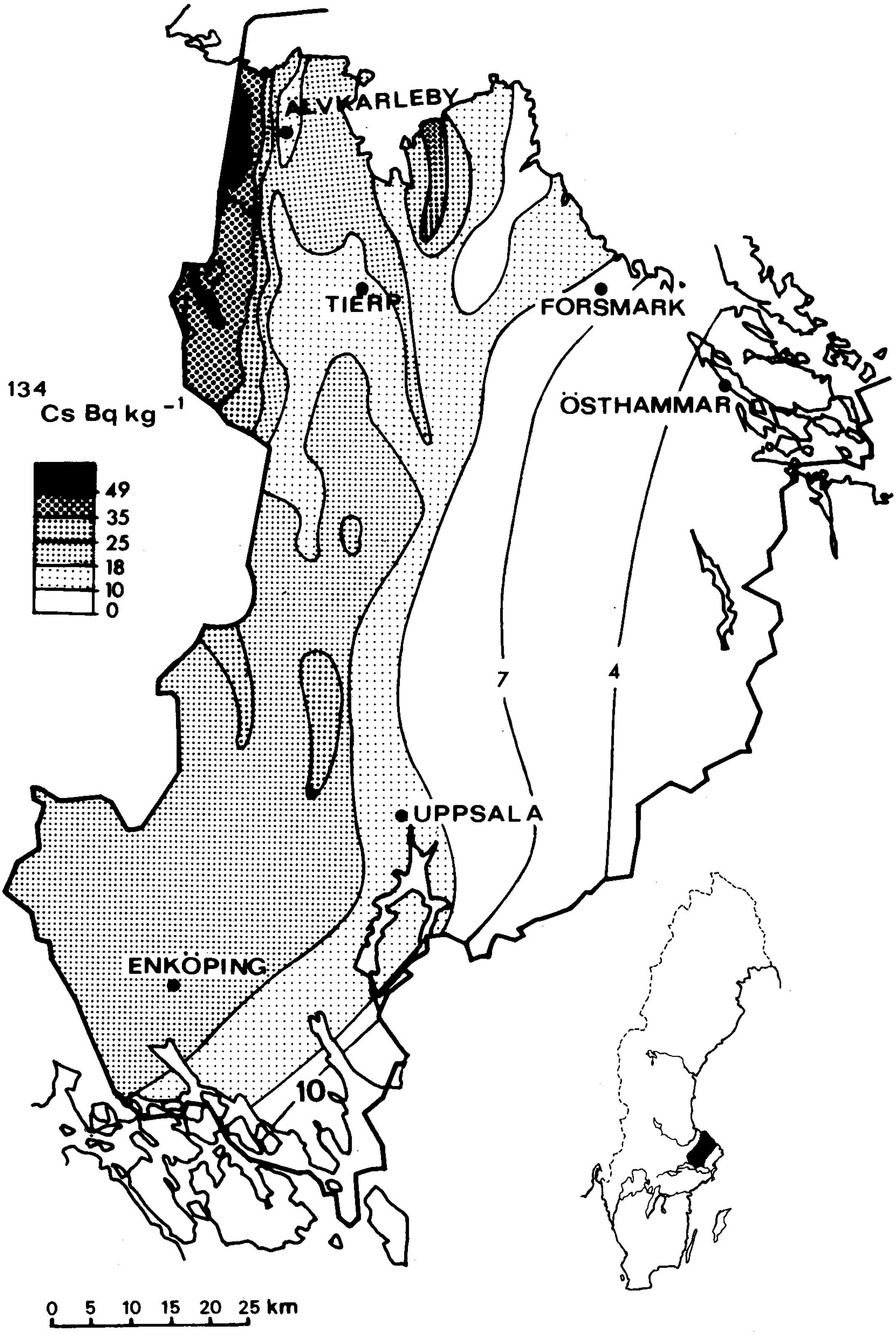

Fig. 1. Fallout from Chernobyl over Sweden, Uppland. Measured by air survey May 9 to June 3, 1986 as kBq/m^2.

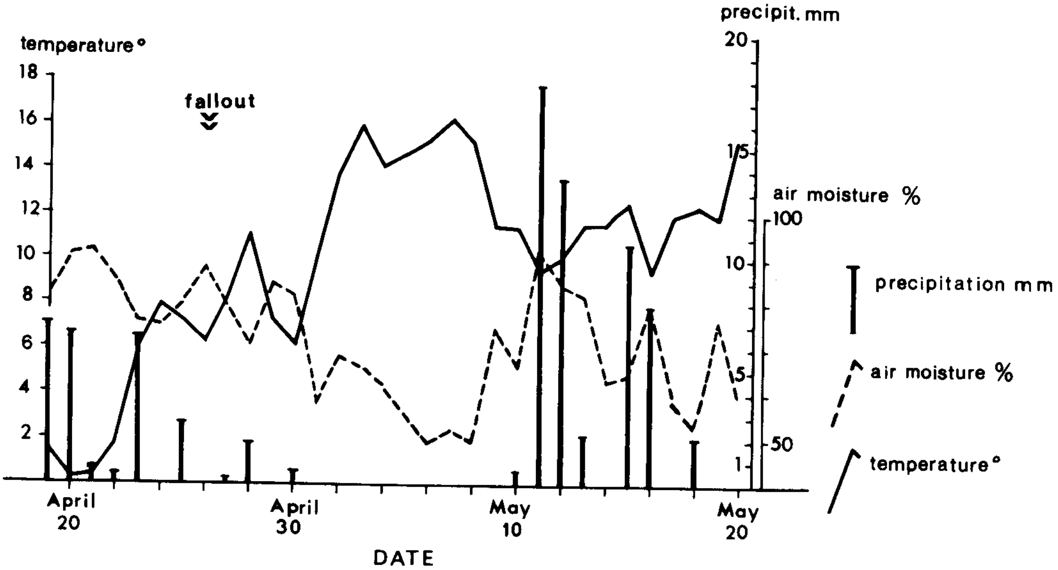

Fig. 2. Abiotic factors during main fallout period, 1986. Measurements by the Department of Meteorology, Uppsala University.

Table 1. Radionuclides in *Aedes communis* pupae compared to those in bottom substrate and in a diatom (*Melosira*) from Central Sweden 1986, expressed in Bq/kg^{-1} dry weight. (Numbers in brackets = s% in measure).

Radio-nuclide	$T_{½}$	Pupae		Substrate		*Melosira*	
		May 18	Oct. 2**	May 18	Aug. 19	Oct. 2**	May 4
60_{Co}		–	40 (38)	–	5 (27)	–	–
95_{Zr}	64.0 days	100 (8)	–	3,300 (1)	230 (6)	130 (17)	<
95_{Nb}	35.1 days	610 (2)	–	7,000 (1)	450 (3)	300 (7)	370 (12)
103_{Ru}	39.5 days	1,060 (1)	–	3,600 (1)	150 (9)	250 (11)	6,400 (2)
110_{Ag}	253.0 days	750 (1)	50 (100)	50 (12)	42 (19)	90 (29)	390 (13)
131_{I}	8.5 days	5,000* (3)	–	2,000* (12)	–	–	31,000 (0.8)
134_{Cs}	2.1 yrs	1,300 (1)	130 (23)	1,600 (1)	1,080 (2)	2,300 (1)	7,400 (2)
137_{Cs}	30.1 yrs	2,300 (1)	250 (7)	3,300 (1)	2,260 (1)	5,700 (1)	13,700 (1)
140_{Ba}	12.8 days	2,400 (8)	–	1,000 (17)	–	–	3,200 (14)
141_{Ce}	33.0 days	80 (21)	–	3,400 (1)	70 (13)	–	<
144_{Ce}	284.0 days	80 (10)	–	3,600 (2)	440 (8)	150 (23)	<

* Calculated back to sampling date.
** Nearby ditch.

radionuclides found in the May sample were barely traceable and thus could not be quantified in pupae from October (Table 1).

The dry substrate from the temporary pool in August 19 still had high values of ^{134}Cs and ^{137}Cs. Substrate samples (leaves and pine needles) taken in October in the nearby ditch had higher concentrations of these radionuclides than May samples from the temporary pool. An explanation could be that the ditch is fed from a much larger area of incoming precipitation and the autumn rains may have washed further radionuclide material into the ditch. By such differences in the water supply, uneven distribution of fission products might occur even within a small area. The availability of cesium nuclides for longer periods in the upper layers of a bottom substrate may influence the biological cycle of radionuclides in temporary habitats in different ways.

From the same fallout period, Mikkola and Albrecht (1986) showed contamination of Finnish lepidopterans collected by a light trap. Radioactivity was measured as pulse frequencies and 14 radionuclides were reported with a low level of radiation over the entire sample. It is suggested that one species caught had been migrating into Finland.

Under more stable conditions, as in the Baltic, a series of fission products were found in various organisms (U. Grimås, unpublished data). Initially the levels of ^{137}Cs (Bq/kg^{-1} dry weight) were high in algae (Cladophora 11,000), but low in invertebrates (Gastropoda 400; Crustacea

300; filter-feeding molluscs as *Mytilus edulis* 130). In August the level had increased to 400 in *Mytilus*. This illustrates the time lag in accumulation of radionuclides in some slowly developing, primary consumers.

In Central Europe fallout from Chernobyl in rain and air was studied, and especially the incorporation of ^{137}Cs into the terrestrial food chain through the grass *Lolium* (Bangert et al. 1986). The values (500–1,800 Bq/kg^{-1}, dry weight) were close to the ^{134}Cs measurements made over Uppland (Fig. 1). But they were much less than in our samples of dead organic material from two substrate sources in a mixed forest at Uppsala, and less than the values found in the pupae during May (Table 1).

In our substrate samples the presence of ^{134}Cs and ^{137}Cs was stable until August and even higher in an adjacent habitat in October. In living organic matter (grass), Bangert et al. (1986) found a beginning decrease of ^{137}Cs during June. Convergently, we found a marked decrease of both ^{134}Cs and ^{137}Cs in the autumn pupae, and except for ^{60}Co and ^{110m}Ag, no other radionuclides at all. The high values of ^{131}I in the May pupae compared to the substrate content and the autumn pupae may partly depend on air intake by the larvae and pupae and partly on the linkage of available radionuclide with the body muscles. During larval development, the muscles grow rapidly and are directly taken over by the motile pupa. The biological influence of ^{131}I might be immediate but temporally limited by its short half-life (T½). The same temporal limitation applies to ^{103}Ru and ^{140}Ba (Table 1). However, ^{134}Cs and ^{137}Cs, with long half-lifes and a metabolic uptake similar to potassium, could become a more stable source of radiation in organisms without compensatory exchange mechanisms in cells. Rearing of the spring population for taxonomic purposes, showed no general trends of negative effects on eclosion ability of males or females. The autumn population in the field had severe losses from night frosts and few adults were found after mid-October.

The presence of an autumn population in the usually univoltine *Ae. communis* and development into adults is only possible in the Uppsala area by a very favorable combination of rains and warm weather in September. Thus this rare event helped us to verify the declining uptake of radionuclides into the aquatic food chain by suspension-feeding insect larvae when several months had passed after the deposition. In the autumn, conditions for larval growth and pupation were good in the field. Larvae of *Ae. communis* are obligate brushers, coprophagous (Nilsson 1983), and facultative suspension feeders on flocculate material and primary producers like bacteria and other microorganisms. This feeding strategy in small temporary pools and ditches should make radionuclides, already incorporated into the food chain by primary producers, a very substantial part of the uptake.

If larval feeding had added the main part of radionuclides to the pupal bodies in May, similar high radionuclide values should have been obtained from the autumn pupa. This was not so. We suggest that the main uptake from fallout until May 18 was not by feeding, but by direct contamination through respiration and accumulation in the water. The processing of radionuclides through the food chain with similar substrate values during autumn (Table 1), may be influenced by differential uptake by the larval bodies; this should be analyzed by experimental studies.

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