ON THE COEFFICIENT OF ACCUMULATION OF RADIOISOTOPES OF SOME CHEMICAL ELEMENTS BY AQUATIC INSECTS

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When we try to specify the contribution of particular species of living organisms to a biogeocenosis it is important that we should know the coefficients of accumulation (CA) of various chemical elements, particularly minor and trace elements (Timofeyev-Resovskiy, 1957, 1962). The CA is defined as the ratio between the concentration of the element in the organism and its concentration in the environment.

It has been part of our duties to determine the CA of certain chemical elements in the form of their radioactive isotopes by larvae of certain aquatic insects. There have been few previous works on this subject (Hasset and Jenkins, 1951; Agranat, 1958; Getsova, 1959a and b; Peredel'skiy and Bogatyrev, 1959a and b; Timofeyev-Resovskiy et al., 1960a and b; Getsova and Volkova, 1961, 1962a-c; Volkova, 1963).

In this communication we present data on the CA of the radioactive isotopes of 14 chemical elements (P^{32}, S^{35}, Fe^{59}, Co^{60}, Zn^{65}, Sr^{90}, Y^{91}, Ru^{106}, Ag^{111}, J^{131}, Cs^{137}, Ce^{144}, Pm^{147} and Hg^{203}) by four species of aquatic insect larvae: dragonflies (Leucorrhinia rubicunda L.), mayflies (Cloëon dipterum L.) caddisflies (Glyphotaelius punctatolineatus Retz.) and drone flies (Eristalis tenax L.).

The method adopted was that used in the biophysics laboratory of the Urals branch of the USSR Academy of Sciences. A 1.5–2 cm layer of lake sand was placed in each of a number of tanks containing a definite amount of lake water, together with twigs from higher aquatic plants (water thyme, hornwort, water milfoil) and one of the insect species under study. Approximately 10μ Cu of one of the radioisotopes enumerated above were introduced into each tank. Samples of the insects and of the water were taken on the 2nd, 4th, 8th and 16th days. The counts were taken by standard methods, with a B-2 apparatus with end-window counter. A correction was made for decomposition in the case of samples containing short-lived elements and for self absorption.

The results of the CA tests for each species of insect studied are shown in the Tables.

Table 1 contains data on the accumulation of radioisotopes of 13 chemical elements by larvae of the dragonfly Leucorrhinia rubicunda L. As can be seen, the CA values range from unity to thousands, depending on the element. The highest CA are shown by iron, yttrium, cobalt (7080, 5025, 4680) and the lowest by strontium (3, 8; 8, 9). The rate of accumulation increased during the first days of the experiment but after 8–16 days some stabilization was observed in most elements. The increased CA in the case of iron, zinc and mercury even on the 16th day was due mainly to the drastic fall in the activity of the water (19, 42 and 44 respectively) while the concentration of radioisotopes in the insects hardly varied.

Table 2 gives the CA for 12 radioisotopes in larvae of the mayfly (Cloëon dipterum L.). Zinc and iron gave the highest values (15858 and 11130), sulfur and strontium the lowest (38 and 51). The CA for the majority of the elements increased throughout the experiment, except in the case of phosphorus, strontium, cesium and cerium, for which it seems that statistical equilibrium set in by the 16th day.

On examining Table 3 one is struck by the comparatively

Table 1

Accumulation of radioisotopes of chemical elements by larvae of the dragonfly Leucorrhinia rubicunda L.

	P^{32}	S^{35}	Fe^{59}	Co^{60}	Zn^{65}	Sr^{90}	Y^{91}	Ru^{106}	J^{131}	Cs^{137}	Ce^{144}	Pm^{147}	Hg^{203}
After 2 days	210	1.4	2320	3970	463	7.9	2200	36	81	50	375	442	1470
After 4 days	417	2.3	4030	4210	775	9.9	3650	56	158	65	700	1020	1815
After 8 days	183	3.6	5670	8340	1000	7	5950	114	83	40	1380	1160	—
After 16 days	372	8	16300	2070	3550	10.6	8300	125	284	37	422	2900	8310
Average . . .	293	3.8	7080	4648	1447	8.9	5025	83	151	48	719	1380	3865

Table 2

Accumulation of radioisotopes of chemical elements by larvae of the mayfly Cloëon dipterum L.

	P^{32}	S^{35}	Fe^{59}	Co^{60}	Zn^{65}	Sr^{90}	Y^{91}	Ru^{106}	J^{131}	Cs^{137}	Ce^{144}	Pm^{147}
After 2 days .	—	5.8	—	422	—	36	—	28	—	567	1920	—
After 4 days .	6350	16.6	1260	558	5150	40	1135	55	154	298	1600	42.5
After 8 days .	13300	34.3	4330	1270	14825	67	4270	104	412	880	3090	485
After 16 days .	9500	89	27800	2840	27600	60	5960	212	690	895	2480	1130
Average	9717	38.4	11130	1272	15858	51	3788	100	419	660	2272	552.5

Table 3

Accumulation of radioisotopes of chemical elements by larvae of the caddisfly Glyphotaelius punctatolineatus Zett.

	P^{32}	S^{35}	Fe^{59}	Zn^{65}	Sr^{90}	Y^{91}	Ru^{106}	J^{131}	Cs^{137}	Ce^{144}	Pm^{147}	Hg^{203}
After 4 days .	2800	17.8	2350	1880	52	3360	470	109	347	1295	113	2000
After 8 days .	4300	60	4600	3530	86	1700	1010	155	293	1560	207	3450
After 16 days .	4600	99.3	8050	7900	72.5	4470	1670	164	135	2220	765	5240
Average	3900	58	5000	4427	70	3177	1050	143	258	1692	362	3563

Table 4

Accumulation of radioisotopes of chemical elements by larvae of the drone fly (Eristalis tenax L.

	P^{32}	S^{35}	Fe^{59}	Co^{60}	Zn^{65}	Sr^{90}	Y^{91}	Ru^{106}	Ag^{111}	J^{131}	Cs^{137}	Ce^{144}	Pm^{147}
After 2 days	750	0.8	710	31	130	13.9	1140	54	320	62.5	24	205	218
After 4 days	2040	3.4	536	47	410	36.7	1130	67	360	606	15	265	298
After 8 days	1510	5.9	668	162	2090	60	4520	132	500	595	37	805	672
Average . . .	1430	3.4	638	77	877	38.9	2263	84	393	421	25	425	396

slight variability of the CA in caddisfly larvae. Here it is difficult to distinguish the highest CA, for a group of elements (P, Fe, Zn, Y, Hg) give very much the same values. As in the other insects, the sulfur and strontium CA are low. Since the CA counts were started, in this experiment, on the 4th day, in other words at the time near the onset of statistical equilibrium (which has been established in repeated experiments on accumulation), the CA varies only very slightly with time, fluctuating around a mean value.

Table 4 gives the results of experiments on the accumulation of 13 radioisotopes by larvae of the drone fly (Eristalis tenax L.). Here the CA of the different elements were lower as compared with those in the other insects investigated. Yttrium and phosphorus stand out as having the highest CA (2263 and 1430). The CA for iron, silver, iodine, cerium and promethium were roughly identical; the lowest CA was for sulfur. Cobalt and ruthenium showed unexpectedly low CA.

Comparing the CA figures for the four species of insects, we can say that the highest values relate to the same five elements — P, Fe, Co, Zn and Y, although the particular element accumulated in greatest amount varies according to the species of insect. In Eristalis, for example, accumulation is greatest in the case of yttrium, followed by phosphorus; in mayflies, the corresponding elements are zinc and iron, in caddisflies iron and zinc and in dragonflies iron, yttrium and cobalt.

The CA of the majority of the elements increases during the first few days; then, as in other accumulation experiments, the CA increases gradually and after 8–16 days statistical equilibrium is established.

The CA varies greatly from one to another of the four species of insects from different systematic groups. The highest CA are characteristic of the mayfly larvae; the CA for dragonflies and caddisflies are roughly the same; the CA for Eristalis larvae are considerably lower.

Why the accumulation of a particular element should vary from one insect to another is still difficult to explain. It looks as though accumulation depends mainly on the physical-chemical properties of the element, but also on the form in which it occurs in solution — whether it is suitable or unsuitable for use by the organism. In addition, accumulation depends on the specificity of the species concerned.

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