RADIOACTIVITY OF SUSPENSOIDS IN AQUATIC ENVIRONMENTS OF NORTHWESTERN OHIO

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During the 5-year period of June, 1957, to May, 1962, a study of aquatic habitats of northwestern Ohio was carried on by staff-members and students of the Biology Department at Bowling Green State University (Verduin, 1959, 1960, 1961a, 1961b, 1962; Verduin, Cowell, and Whitwer, 1959).

The research was subsidized by the Atomic Energy Commission, contract AT(11–1)–536. One aspect of the study involved determination of levels of gross beta radioactivity in samples collected from the natural environment. Because an experimental nuclear reactor was under construction at Plumbrook, near Sandusky, Ohio, the streams of that vicinity were the object of intensive study by members of the Health Physics Department at the reactor site. Water samples of 500 ml each were collected periodically from five locations near Sandusky, and were first filtered through millipore filters (0.45 μ pore diameter) then evaporated to collect the dissolved solids. The filters were counted for gross beta activity in a gas-flow counter, as were also the dissolved solids. Mr. Wisdahl, of the reactor Health Physics Department, kindly consented to send the millipore filters to the BGSU Biology Department for further study, after their gross beta radioactivity had been determined in his laboratories.

In our laboratories these filters were weighed, their gross beta activity determined in a Nuclear-Chicago D–47 gas flow counter, and the filters were then cleared with cedar oil and studied microscopically under 430$\times$ magnification to count, identify, and measure the phytoplankton cells in 10 fields on each filter. The phytoplankton volumes were computed in microliters per liter of water using the following formula:

$$\frac{V \times 2 \times 10^{-9}}{\frac{A}{9.6}} = \text{microliters of phytoplankton per liter of natural water}$$

Where V = cubic microns of phytoplankton observed in 10 fields

A = area of 10 fields in cm^2.

The factor of 2 is used because only one-half liter was filtered. The factor 9.6 represents the active area of the millipore filter disc in cm^2, and the factor 10^{-9} converts cubic microns to microliters. A sample determination appears in table 1.

The major objective of these determinations was to obtain values for gross beta radioactivity in terms of $\mu\mu$curies per gram of suspensoids and to correlate these values with the phytoplankton volumes to determine whether much of the radioactivity were concentrated in phytoplankton. The data so obtained are presented in table 2. For the purpose of this comparison all samples containing more than 0.2 microliters of phytoplankton per liter were combined in a single average (5 samples), all those lying between 0.19 and 0.060 were averaged (8 samples), and those containing less than 0.059 were averaged (9 samples). The data in table 2 (see graph in fig. 1) show that there was not a positive correlation between radioactivity and phytoplankton volume, on the contrary there seems to be a negative correlation. However, the phytoplankton volumes are very low, averaging less than one-tenth of the winter season values for western Lake Erie (Verduin, 1960). The phytoplankton fraction of the total suspensoids is less than

1 percent, by weight, hence their apparently insignificant contribution to the observed radioactivity is not surprising.

Table 3 presents a comparison of the gross beta radioactivity of suspensoids from the five different collection sites. The data were divided into three groups, representing two consecutive sets of five collections each, and a third set of eight. The first two sets yielded detectable levels of radioactivity but after February 24 the counts were similar to background counts indicating that quantitics of radioactivity present were too low to be detected with our instrument. No significantly consistent differences appear among data from different collection sites. The scatter apparent in the averages in table 3 is evidence of the spotty distribution of fallout. Gross beta radioactivity on individual samples varied from zero to 1884 $\mu\mu c/g$ of suspensoids.

TABLE 1

Sample phytoplankton computation from millipore filter data.

Genus	Dimensions in microns	Number in 10 fields	Volume in 10 fields (μ^3)
Gomphonema	74×16×13	1	15200
"	16×8×6	3	2300
"	36×6×5	1	1100
Synedra	42×6×4	1	1000
Navicula	24×6×5	5	3600
"	64×5×5	2	3200
Diploneis	16×8×8	1	1000
	Total volume in 10 fields (μ^3)		27,400

Area of 10 fields $= 0.96\times10^{-2}$ cm^2

$$\frac{\dfrac{27{,}400\times2\times10^{-9}}{0.96\times10^{-2}}}{9.6} = 0.055 \text{ microliters per liter}$$

TABLE 2

Correlation of beta radioactivity of suspensoids with volume of phytoplankton and dry weight of suspensoids.[1]

Average beta-radioactivity $\mu\mu c/g$	Average volume of phytoplankton μl/liter	Average dry weight of suspensoids mg/liter	Number of samples used to compute average
238	0.32	48	5
390	0.11	74	8
450	0.03	98	9

[1]Data collected during January, 1960, from five river locations near Sandusky, Ohio.

In table 4 data from three areas are compared. The radioactivity in the rivers near Sandusky was lower than that observed in Urschel's Quarry, on the Bowling Green State University campus, and a collection from a sphagnum bog near Buckeye Lake, Ohio, revealed the highest radioactivities observed during 1960. The ash from sphagnum samples showed a radioactivity of 4500 $\mu\mu c/g$. It seems likely that the upper decimeter of water in such a bog accumulates fallout and the sphagnum absorbs it from the water. In a pond such as Urschel's Quarry, having a depth of 3 m, the fallout accumulates but is dispersed throughout the entire water mass, while rivers and creeks, like those sampled near Sandusky, contain only the debris from recent rains and perhaps some accumulated debris picked up as the rain washes over the soil.

TABLE 3

Comparison of beta radioactivity of suspensoids from five different collection sites ($\mu\mu c/g$).

Location:	Huron River at Milan	Huron River at Huron	Plum Brook	Pipe Creek	Mills Creek
Period and number of collections:					
11/18/59 to 1/13/60, 5 collections	180	275	171	403	1182
1/20/60 to 2/17/60, 5 collections	70	241	475	211	294
2/24/60 to 4/13/60, 8 collections	0	82	0	0	17

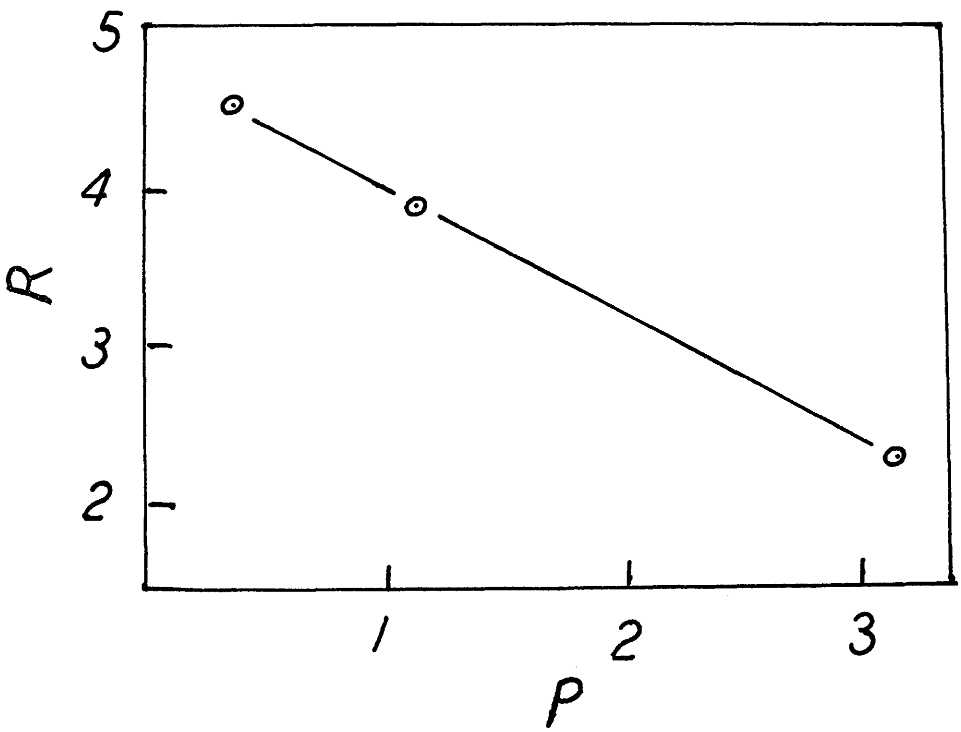

FIGURE 1. Radioactivity of suspensoids (R, numbers are hundreds of $\mu\mu$curies per gram of suspensoids) graphed against phytoplankton volume (P, numbers are tenths of a microliter per liter). A negative correlation is apparent.

The data in table 4 show that the suspensoids in the rivers of the Sandusky area and in Urschel's Quarry contained about 23 times more radioactivity per gram than was present in the dissolved solids. The insignificant fraction of phytoplankton in the river samples (table 2) leads one to infer that the radioactive particles either are adsorbed on the non-living suspensoids, or are themselves of a size large enough to be collected on the millipore filter. The sphagnum data reveal that sphagnum ash contains a concentration of radioactivity 12 times higher than that present in the dissolved solids of the bog water. Here again we are unable to distinguish among processes of mechanical trapping of suspended particles, adsorption on the surface of sphagnum plant parts, and actual absorption and incorporation within the plant tissue. The concentration factor of 12-fold for sphagnum ash has a different basis than the several hundred fold concentration factors reported in the literature (Williams and Swanson, 1958, for example). Such high concentration factors are obtained by dividing the radioactivity per gram of fresh plant by the radioactivity per ml of environmental water. In the case of the sphagnum bog, the environmental water contained about 0.073 $\mu\mu c/ml$ and the sphagnum contained about 40 $\mu\mu c/g$ of fresh plant, yielding a concentration

TABLE 4

Average values of radioactivity of suspensoids, of dissolved solids, and of ash from a Sphagnum collection, all obtained during 1960.

Location	5 river locations near Sandusky, Ohio	Urschel's Quarry Bowling Green, Ohio	Sphagnum bog near Buckeye Lake, Ohio
Radioactivity of:			
Dissolved solids $\mu\mu c/g$	17	57	377
Suspensoids $\mu\mu c/g$	380	1300	
Sphagnum $\mu\mu c/g$ of ash			4500
Weight of dissolved solids mg/liter	560	200	193

factor of 550. In my opinion, the 12-fold concentration factor which is the ratio of radioactivity per gram of plant ash to the radioactivity per gram of solids in the water is more revealing, although less spectacular, than the other number. It is well known that aquatic plants accumulate an ash content several thousand-fold greater than is contained in the environmental water. For example, Lake Erie diatoms have an ash content representing about 31 percent of their fresh weight (Verduin, 1954) but the dissolved solids in the water represent only 1.7 parts per 10,000 indicating a concentration factor of $31 \times 10^{-2}/1.7 \times 10^{-4} = 1800$. This comparison is presented here to counteract a wide-spread notion that plants have a pernicious tendency to concentrate radioactive substances. This is not the case. Their tendency to concentrate non-radioactive substances reveals "concentration factors" similar to those reported for radioactive materials.

Students who contributed to this study are Roger P. Flower, who made the analyses of Urschel's Quarry samples and the sphagnum bog samples, and Terry L. Hufford who analyzed the Plumbrook samples.

SUMMARY

Suspensoids in aquatic environments of northwestern Ohio contained between 12 to 23 times more radioactivity per gram than was present in the dissolved solids

of the environment. No positive correlation was observed between radioactivity of suspensoids and phytoplankton volume. The river phytoplankton volumes represented less than 1 percent of the suspensoids. Sphagnum plants from a bog showed higher concentration of radioactivity, per gram of ash, than was present in the suspensoids. When the concentration factors were computed as ratio of radioactivity per gram of fresh plant weight to the radioactivity per ml of environmental water a concentration factor of 550 was obtained. It is pointed out that similar concentration factors are obtained for non-radioactive portions of plant ash.

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