timately result in faster metabolic rates.

The fact that not only surface-born bacteria (*11*) but also microorganisms collected at the deep-sea floor are exhibiting extremely slow metabolic rates when incubated in situ may be interpreted in two ways.

Life processes in general may be slower at deep-sea conditions than at surface pressures and temperatures for reasons other than the low nutrient supply. Studies on the deep-sea benthic fauna (*7*), have reported (i) extreme diversity of species, (ii) small brood size, (iii) preponderance of adult individuals in most species, and (iv) abundant cases of endemism. These characteristics suggest slow growth and long life of the individual animal and could be the result of a relative retardation of certain critical metabolic processes.

The slow metabolic rate may also lead to the argument that an active, adapted microflora does not exist in the deep-sea sediment. The high colony counts usually found when deep-sea sediment samples are streaked on nutrient agar (*5*) may originate solely from surviving and viable cells that reached the ocean floor with sedimenting detritus particles. Particulate organic matter readily available for microbial decomposition will hardly reach the deep ocean. It will largely be degraded during the slow sedimentation, estimated to take from several weeks to more than a year per 1000 m of depth (*8*). The particulate organic matter in deep waters was shown to be "refractory" (*9*), that is, no degradability could be demonstrated. The total amount of larger particulate material (for instance, animal carcasses) reaching the deep sea undegraded will probably be very small, although of considerable significance for the highly diverse but scanty fauna of benthic scavengers. Nothing is known about the quantity of nonrefractory organic matter reaching the deep-sea floor with the relatively fast-sinking fecal pellets of zooplankton (*8*).

Thus, the top sediment being virtually void of nonrefractory organic matter readily available for degradation, the activity of microorganisms in the deep sea may be largely confined to intestinal tracts of animals, where the enriched nutrient milieu will enable microorganisms to decompose refractory materials (chitin, cellulose, and so forth) in an endosymbiotic fashion. This notion is supported by the finding of an enlarged gut in deep-sea mollusks (*10*). According to this hypothesis, the role played by microorganisms in the turnover of organic matter in the deep-sea sediments appears to be fundamentally different from that in shallow-water sediments, or, for that matter, in soil. Experiments on incubations of solidified organic materials (agar, starch, gelatin) on the deep-sea floor in open containers (*11*) show that after 1 year of exposure, marks of animal feeding appeared to be almost the only sign of disintegration. No work on the intestinal flora of deep-sea invertebrates has yet been done. Complementing our earlier work (*1*), the data reported in this study confirm the conclusion that the deep sea must be considered extremely inefficient with respect to recycling of organic wastes.

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12. We thank P. Holmes for assistance in one of the *Alvin* dives; and J. M. Teal, J. F. Grassle, and K. L. Smith for a critical discussion of the manuscript. Research supported by NSF grant GA 33405. This is contribution No. 2987 of the Woods Hole Oceanographic Institution.

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Polychlorobiphenyls in North Atlantic Ocean Water

Abstract. *Concentrations of polychlorobiphenyls (PCB's) have been measured at the surface and at various depths in the water of the North Atlantic Ocean between 26°N and 63°N. The concentrations average about 20 parts per trillion and amount to an estimated* 2×10^4 *metric tons of PCB's in the upper 200 meters of water. The average concentrations of PCB's in the surface water of the Sargasso Sea are lower than those in the northern North Atlantic.*

Seawater is the most abundant solvent available for trapping hydrocarbons, such as the polychlorobiphenyls (PCB's), released into the environment. The volume of the oceans (10^{21} liters) is sufficient to dissolve all the PCB's that have been manufactured (*1*). Relatively few measurements have been made of PCB concentrations in open-ocean water to determine the extent to which it functions as a solvent trap (*2*). Most analyses have been confined to organisms (*3*), which comprise less than 1 part per million of the total volume.

During the summer of 1972 we analyzed the PCB concentrations of open-ocean water in the eastern and western North Atlantic between 26°N and 63°N. The stations and analyses are tabulated in Table 1 (*4*). For samples 1 to 9 and 13 we extracted 19 liters of seawater (*5*) with 2 liters of a hexane-ether mixture (94 : 6), concentrated the extract, and then analyzed it by electron capture gas chromatography (ECGC). For the other samples we pumped 19 to 80 liters of water through a brass or glass column [16 by 2 cm (inside diameter)] packed with Amberlite XAD-2 resin (Rohm & Haas) to a height of 12 cm (*6*) at 250 ml/min. The PCB's were eluted from the column with 300 ml of boiling acetonitrile at full gravity flow. The acetonitrile was then diluted with 1 liter of water (distilled or seawater) and extracted with hexane. The concentrated hexane extract was analyzed by ECGC. No cleanup of the extract was required prior to ECGC. Unfiltered seawater samples collected and analyzed simultaneously with water filtered through a 0.3-μm glass fiber filter or a glass wool plug contained a maximum of 10 percent more PCB than the filtered seawater samples. All analyses were completed on shipboard within 4 hours of sampling (*7*).

Three observations can be made from the data:

1) Although the range is very broad, the concentrations of PCB's in the northern North Atlantic average 35 ng/kg [35 parts per trillion (ppt)] in surface waters, and 10 ppt at 200 m.

2) The PCB concentrations decrease with depth.

3) The surface waters of the Sargasso Sea (stations 25–41) have slightly lower surface concentrations of PCB's (27 ppt) than surface waters in other parts of the North Atlantic.

The widespread distribution of PCB's

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in the open North Atlantic supports previous observations that the atmosphere must be the predominant mode of transport (*3*). The wide range of concentrations observed (< 1 to 150 ppt), in some cases at points only 80 km apart (stations 29 and 33), may be due to seaslicks (*2*), localized rainfall, or discharges from ships. No relationship between PCB concentration and proximity to land was observed. The presence of measurable PCB concentrations, even to depths of 3000 m, suggests that animals which migrate vertically, plus sinking shells, feces, and dead organisms, transport PCB's out of the mixed layer (about 150 m) and prevent even higher concentrations from accumulating in the productive zone.

The Sargasso Sea is an area of high evaporation and low rainfall. We suggest that PCB's, adsorbed on particulates falling into this region, are partially solubilized by equilibrating with the surface water. Evaporative codistillation then transports some of this material to areas of higher precipitation.

The volume of the upper 200 m of the North Atlantic is 10^{18} liters. If we assume an average PCB concentration of 2×10^{-8} g/liter in that volume (*8*), then there may be about 2×10^{10} g (2×10^{4} metric tons) of PCB's in the water (*1*, *9*). The total amount of PCB's produced in the United States in 1971 was 1.8×10^{4} metric tons (*1*).

On the basis of quantitative estimates of rates of production and rates of loss to the environment, a ΣDDT/PCB ratio [ΣDDT refers to DDT, 1,1,1,-trichloro-2,2-bis(*p*-chlorophenyl) ethane, and its major metabolites] of 10 is expected in the North Atlantic, if we assume that the half-lives are similar (*9*). The observed ratio from our data [and from (*2*)] must be less than 0.05 [that is, < 1 ppt/20 ppt (see first footnote, Table 1)]. Thus the environmental half-life of the PCB's appears considerably greater than that of DDT and its metabolites.

Table 1. Concentrations of PCB's in North Atlantic ocean water. The limit of detection was 1×10^{-9} g/liter for a 19-liter sample.

Station	Position		Date (1972)	Depth (m)	PCB concentration* ($\times 10^{-9}$ g/liter)
	North	West			
1	52° 55′	35° 08′	6/30	0	150
2	44° 00′	30° 36′	7/3	0; 200	35; 10
3	40° 33′	29° 16′	7/5	0; 200	4; 7
4	36° 11′	25° 33′	7/7	0; 200	11; 3
5	34° 02′	22° 50′	7/9	0; 200	30; 6
6	35° 00′	18° 59′	7/11	0; 200	14; 5
7	34° 47′	14° 57′	7/13	0; 200	67; 39
8	38° 20′	11° 23′	7/15	0; 200	19; 2
9	38° 23′	11° 11′	7/22	0; 200	41; 13
10	38° 19′	19° 28′	7/23	0	77
11	41° 09′	20° 46′	7/24	0	< 1
12	43° 57′	22° 13′	7/25	0	52
13	43° 20′	21° 57′	7/27	0	47
14	43° 16′	21° 34′	7/29	100; 3000	45; > 1†
15	46° 31′	21° 43′	7/30	0	10
16	52° 31′	19° 52′	8/1	0; 100	45; 8
17	52° 35′	19° 53′	8/2	1500	> 1†
18	55° 41′	15° 02′	8/4	0	3
19	57° 22′	12° 01′	8/5	200	97
20	60° 04′	06° 02′	8/6	200	42
21	60° 09′	05° 36′	8/7	0	82
22	60° 29′	04° 43′	8/7	0	23
23	63° 03′	02° 22′	8/8	0; 200	21; 7
24	41° 32′	70° 40′	10/2	0	30
25	39° 40′	70° 03′	9/21	0	29
26	37° 12′	68° 54′	9/22	0	36
27	34° 32′	67° 01′	9/23	0	12
28	35° 22′	67° 36′	9/24	1000	1
29	35° 17′	68° 28′	9/24	0	2
30	35° 56′	66° 34′	9/25	0	5
31	36° 05′	67° 27′	9/26	0	11
32	36° 24′	68° 24′	9/27	0	22
33	35° 37′	67° 49′	9/27	0	9
34	34° 26′	66° 22′	9/28	0	12
35	33° 41′	65° 44′	9/28	0	15
36	28° 42′	58° 39′	10/3	0	26
37	26° 50′	55° 38′	10/5	0	36
38	25° 56′	54° 15′	10/6	0	27
39	26° 58′	53° 57′	10/7	0	42
40	28° 26′	53° 55′	10/8	0	88
41	31° 13′	53° 49′	10/9	0	68

* The closest matching commercial mixture in all cases was that containing 54 percent chlorine. Thus the commercially available Aroclor 1254 (Monsanto) was used as the standard. Procedural blanks ranged from 0 to 3 ng/liter and were subtracted from the tabulated concentrations; DDT and its metabolites, if present, were present at concentrations less than 1 ng/liter. † Poor match for Aroclor.

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References and Notes

1. The total U.S. production of PCB's since 1957 is about 3.6×10^{11} g [*Chem. Eng. News* (6 Dec. 1971), p. 15] which is estimated to be about one half of the total world production.
2. C. E. Olney and J. G. Quinn, paper presented as part of the deliberations of the International Decade of Ocean Exploration Baseline Conference, E. D. Goldberg, chairman, Brookhaven National Laboratory, Upton, N.Y., 24–26 May 1972 (these workers measured the PCB concentrations in the surface microlayer and 20 cm below the surface in the North Atlantic; their subsurface concentrations agree with our surface measurements, although their sample size was much smaller).
3. G. R. Harvey, V. T. Bowen, R. H. Backus, G. D. Grice, in *Nobel Symposium 20: The Changing Chemistry of the Oceans*, D. Dyrssen and D. Jagner, Eds. (Almqvist & Wiksell, Stockholm, 1972), p. 177; deliberations of the International Decade of Ocean Exploration Baseline Conference, E. D. Goldberg, chairman, Brookhaven National Laboratory, Upton, N.Y., 24–26 May 1972.
4. Stations 1 to 23 were occupied on cruise 107 of R.V. *Chain;* stations 25 to 41 were occupied on cruise 71 of R.V. *Atlantis-II.* Station 24 is the Woods Hole dock.
5. Surface samples were collected in a stainless-steel bucket from the bow of the ship while it was under way. Deep samples were collected in a 160-liter Bodman bottle lined with Kel-F. R. H. Bodman, V. T. Bowen, L. W. Slabaugh, *J. Mar. Res.* 19, 141 (1961).
6. The parameters for the use of this resin given in the text were developed by the authors in this laboratory. The efficiency of the adsorptive extraction, when compared with solvent extraction, is > 95 percent.
7. A Packard gas-liquid chromatograph, model 407, equipped with a ^{63}Ni electron-capture detector was used. No motion sensitivity was observed in the instrument's response. A shipboard analysis revealed that the ship's paints, greases, and oils did not contain any PCB's.
8. These data and (*2*). In contrast, PCB concentrations in coastal northeastern Pacific waters average 1 ppt (I. Barrett, paper presented as part of the deliberations of the International Decade of Ocean Exploration Baseline Conference, E. D. Goldberg, chairman, Brookhaven National Laboratory, Upton, N.Y., 24–26 May 1972).
9. This quantity is remarkably similar to a recently calculated estimate of 1.5×10^{4} metric tons of PCB's in the North Atlantic; no water data were available at the time of the calculation [J. C. T. Nisbet and A. F. Sarofim, *Environ. Health Perspect.* 1, 21 (1972)].
10. We thank Dr. R. H. Backus, chief scientist on cruise 105 of R.V. *Chain*, for allowing us the opportunity to collect those samples and Dr. V. T. Bowen for making the deep samples available. Supported by grant GX 35212 from the Office of the International Decade of Ocean Exploration, National Science Foundation and grant GQ 15020 from the Environmental Protection Agency Woods Hole Oceanographic Institution contribution No. 2798.

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