

Reprinted from the "Proceedings of the Indian Academy of Sciences," Vol. LVI, 1962

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A COMPARISON OF VALUES OF ORGANIC PRODUCTION OBTAINED FROM OXYGEN AND C¹⁴ METHODS*

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Received July 31, 1962

INTRODUCTION

STUDY of marine photosynthesis has been one of the main concerns of marine biological investigations during recent years. With the introduction of radioactive carbon (C¹⁴) by Steemann Nielsen (1952) in the measurement of organic production in the sea, this branch of investigation has received considerable fillip. The great sensitivity of this technique has revealed several complex problems regarding factors influencing plant production. However, regarding the interpretation of C¹⁴ values there has been much discussion as to whether the method measured gross or net production.

In the oxygen method, dissolved oxygen concentration is influenced by the respiration of the whole community including phytoplankton, zooplankton and bacteria. The 'dark' bottle makes the correction for this respiration. Hence the 'light' and 'dark' bottle method gives gross production. It is also possible from these experiments to measure the "net community production" but not the true net production. But Ryther (1956) remarks that gross production is an intangible quantity, whereas net production is the real production of organic matter which is added to the environment and hence of real concern to the ecologist.

In order to have a proper reconciliation of the values obtained by the oxygen and C¹⁴ methods it is essential to have direct comparisons of values of concurrent experiments. But data on these are very scanty and even the available results are mostly for pure cultures.

The authors have been using 'light' and 'dark' bottle method for some time in the study of primary production of the coastal waters of Mandapam. Recently with a consignment of C¹⁴ obtained from the International Agency

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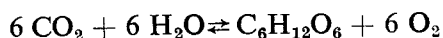
for C¹⁴ determination at Charlottenlund, some *in situ* experiments were also carried out in the inshore waters of the Gulf of Mannar and Palk Bay. Apart from these a few sets of experiments were conducted in an oceanic environment in the Laccadive Sea. Some of these were concurrent experiments.

RESULTS

The photosynthetic values from the oxygen experiments have been calculated using a PQ of 1.01 (*cf.* Prasad and Nair, 1960) and a PQ of 1.25 (Ryther, 1956; Steemann Nielsen—personal communication). Ratios of photosynthetic rates of oxygen to C¹⁴ values also have been worked out.

It may be seen from Table I that in most of the experiments conducted in the inshore waters, the ratios are very near to unity. It has been noticed that when phytoplankton is abundant the results are very close. Only in one instance C¹⁴ experiment has recorded a higher value than the oxygen method. This may be due to the presence of a larger zooplankton population in the 'light' bottle which would have materially reduced the oxygen value. In this particular experiment, the oxygen in the 'light' bottle was less than the initial value indicating a higher respiratory rate. Disconcertingly large ratios have been obtained in certain cases especially with the oceanic water. But since the values for oligotrophic waters using the 'light' and 'dark' bottle method are questionable these ratios cannot be taken into consideration.

It may be mentioned here that McAllister *et al.* (1961) recently measured ratios by the two methods and they remark that a correct PQ value is of very great importance in marine studies for making an accurate estimate of carbon uptake from oxygen measurements. According to these authors, the difference between the results obtained by the oxygen and C¹⁴ methods is mainly due to the non-assessment of the correct photosynthetic quotient for calculating the values of carbon assimilation. It has been the usual practice in oxygen experiments to determine the glucose-carbon equivalent by multiplying the volume of the oxygen produced by 0.536 (or mass of the oxygen produced by 0.375). This is on the assumption of a PQ of unity, following the familiar equation:



But Ryther (*loc. cit.*) remarks that a PQ of unity is largely an experimental artifact and values of 1.1 to 1.3 or higher are normal under natural conditions. Since it is impossible to choose the correct value for routine measurements of natural populations, he suggests a value of 1.25 as more realistic than 1. He also noted striking agreement for measurements of photosynthesis with

TABLE I

Serial No.	Date	Station		Carbon assimilation as mg./M ³ /day			Ratio: O ₂ value/C ¹⁴ value			
				C ¹⁴ Method	Oxygen Method			PQ=1.01	PQ=1.25	PQ=1.3
					PQ=1.01	PQ=1.25	PQ=1.3			
1	21-12-1960	Gulf of Mannar	S	265.568	389.07	315.62	302.41	1.46	1.19	1.14
2	do.	do.	B	127.717	161.65	131.15	125.66	1.27	1.03	0.98
3	13 6-1961	Palk Bay	S	24.835	62.01	50.31	48.20	2.50	2.03	1.94
4	do.	do.	M	27.559	31.33	26.23	25.13	1.14	0.95	0.91
5	do.	do.	B	36.316	208.29	168.99	161.92	5.74	4.65	4.46
6	16-4-1961	Androth	M	8.546	91.69	74.39	71.28	10.73	9.13	8.34
7	do.	do.	B	5.249	133.56	108.36	103.82	25.44	20.64	19.78
8	22-4-1961	Minicoy Lagoon	S	38.224	133.56	108.36	103.82	3.49	2.83	2.72
9	12-6-1961	Palk Bay	S	434.939	558.09	452.79	433.84	1.23	1.04	1.00*
10	do.	do.	B	97.212	80.03	64.93	62.21	0.82	0.67	0.64

S = Surface

M = Middle layer

B = Bottom

* Phytoplankton bloom

oxygen and C¹⁴ methods simultaneously with a pure culture of *Dunaliella euclora*, with the above PQ. Steemann Nielsen (1952) also had mentioned that the oxygen method must be regarded as giving a greater yield of 33 per cent. than the C¹⁴ method and he has put the photosynthetic quotient at 1.33 for this comparative experiments with cultures of *Scenedesmus*.

For Chlorophyceae and diatoms, most of the PQ values given in the literature are very low, being around 1.05 (*cf.* Strickland, 1960). With raw sea-water, Sargent and Hindman (1943) obtained the CO₂/O₂ ratio of 0.95 which they consider not significantly different from unity and hence they presume the values found by Barker (*see* Ryther, 1956: Table II) of 1.05 to 1.08 to be characteristic of the whole phytoplankton community. [It may be pointed out here that Rabinowitch (1945) has cautioned, that for photosynthetic quotient $Q_p = \Delta O_2 / - \Delta CO_2$, many authors have designated the inverse ratio $-\Delta CO_2 / \Delta O_2$ and that care should be taken in the quotation of numerical results.] Strickland (*loc. cit.*), who has fully reviewed the measurement of phytoplankton production, interpreted the above low value for raw sea-water as due to the reduction of measured PQ brought about by the respiration of zooplankton and bacteria and has suggested an approximate working value of 1.2.

From the above account it may be seen that the general consensus is not in favour of assuming the photosynthetic quotient as unity for estimating the carbon uptake from oxygen experiments. From the data so far obtained from our experiments it is felt that a PQ of little over 1.25 would give comparable results especially in the inshore waters and that when phytoplankton is abundant C¹⁴ values approximate gross production. Hence a working value of 1.3 (1 ml. of O₂ = 0.412 mg. C) is suggested for the estimation of carbon uptake from oxygen experiments.

ACKNOWLEDGEMENT

The authors are deeply indebted to Dr. S. Jones, Director, Central Marine Fisheries Research Institute, for encouragement. They are also thankful to Shri R. Jayaraman for helpful discussions.

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APPENDIX

Since this paper was prepared and submitted for publication, the authors came across the note "Primary organic production off Waltair coast" by D. V. Subba Rao and P. N. Ganapati [*Curr. Sci.*, 1962, 31 (6), 242] and felt that there is some confusion in the results reported there and hence this Appendix.

In Table I the organic production values derived from the oxygen technique and expressed in mg. C/M³/6 hours do not seem to reconcile with values obtained from the C¹⁴ method. If the values given in columns 11-12 under the title "Dark and light bottle tech...." are really the carbon equivalents of oxygen production, as indicated by the unit of expression, then the values seem to be considerably high because of the fact that the standing crop of phytoplankton in terms of numbers of cells per litre or pigment units as observed by the same authors for this region is not very high (*cf.* Ref. 3 of the note). Data of *Galathea* station 303, which the authors refer to as a typical coastal station, during the period of primary maximum, shows only about 12 mg. C/M³/6 hours at the surface. The values given in column 13 are of course reasonable for the period of secondary maximum which presumably may be the basis of the authors' remark that the magnitude of organic production during the primary peak is more than twice the secondary. But since the authors further state that from the C¹⁴ data the total amount of carbon assimilated by algae is calculated employing Doty and Oguri's formula, it is difficult to find out whether the values given in column 13 are the fractions of tracer carbon fixed or total carbon. If the values given in column 13 represent the primary production as mg. C/M³/6 hours as indicated by the title, it is actually the total amount of carbon fixed by the algae. So it is not understood how Doty and Oguri's formula has been applied to arrive at the values given in column 14. Besides, it could be seen that for the stations where experiments have been carried out, the total CO₂ of sea-water, calculated from the carbonate alkalinity derived from the hydrographical data presented in Table I, does not appear to reach the level of the oceanic waters (*i.e.*, 90 mg./l.).