A methodology to assess the biochemical oxygen utilization and production in estuarine ecosystems

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ABSTRACT

The procedures presently followed for the determination of BOD and COD of coastal waters are complicated, time consuming, and expensive leading to practical difficulties in the field laboratories of aquaculture farms and research organisations, without serving the purpose at times of emergency. The objective of the present study is therefore to understand as quickly as possible whether the water by nature provides an oxidizing or reducing environment and to know the net rate of biochemical oxygen consumption / production per hr or day, based on a simple light and dark bottle technique of oxygen estimation by Winkler's method with an incubation of 2-3 hrs, assuming that light bottle gives the net production/consumption value of oxygen for the day time and dark bottle for the night time. This modified technique was tested in different months at two different coastal water bodies of aquaculture interest in Kerala, viz. (i) the intertidal surf zone of the Moplah Bay at Cannanore and (ii) the Murad estuary (near mouth) situated at about 50 km south of Cannanore. The results indicated that, in general, the net rate of biochemical oxygen consumption was more than production in the Murad estuarine system as compared to the Moplah Bay and it varied much in space and time. The merits of this method and demerits encountered in the estimation of BOD and COD are also discussed.

INTRODUCTION

Dissolved oxygen plays a very important role on the healthy survival of organisms in aquaculture and other coastal ecosystems; and is influenced by the physical, chemical and biological processes of the environment. Biochemical role involving photosynthesis, respiration and other oxidation-reduction processes such as decomposition of organic matter and recycling of mineral influence the rate of consumption / production of dissolved oxygen in the tropical coastal aquatic ecosystems (Fig.1). Further, the physical factors such as temperature, rainfall, freshwater supply, tidal rhythms and connected mixing processes and circulatory pattern govern the

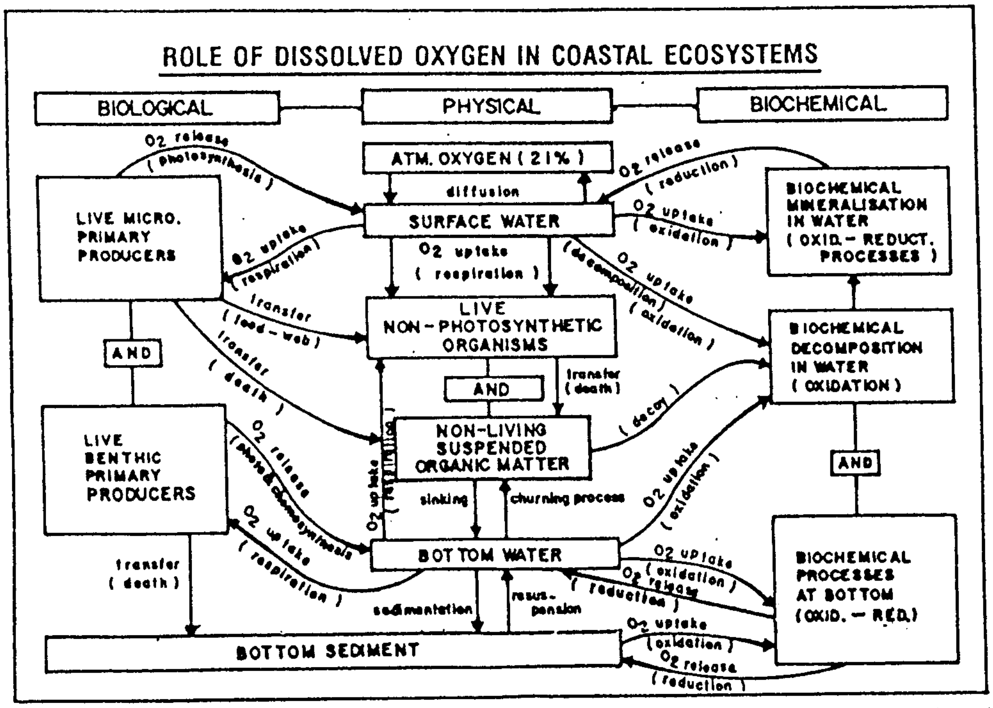

Fig. 1. Physical, chemical and biological processes involved in the utilization / production of oxygen in coastal aquatic ecosystems.

concentration and distribution of dissolved oxygen in the aquatic systems. As a result, the dissolved oxygen level goes on changing in space and time within the coastal ecosystem. In view of these, regualr monitoring of the dissolved oxygen level and the rate of biochemical oxygen consumption / production in the water is essential to maintain a healthy environment especially in the coastal aquaculture systems.

As such, the procedures adopted to determine BOD and COD of coastal waters are complicated, time consuming, and leading to practical difficulties in the field laboratories of aquaculture farms and research organisations, as these techniques do not meet the immediate need at times of emergency. Further, certain techniques adopted in the temperate waters are not directly applicable to our tropical environments. This paper provides the methodology of a simplified technique to determine the net rate of biochemical oxygen consumption / production in the tropical coastal ecosystems, illustrated by the results obtained from two different coastal waterbodies of aquaculture interest in Kerala, viz. (i) the shallow intertidal surf zone of the Moplah Bay at Cannanore and (ii) the Murad estuary (near mouth) situated at about 50 km south of Cannanore (Fig.2)

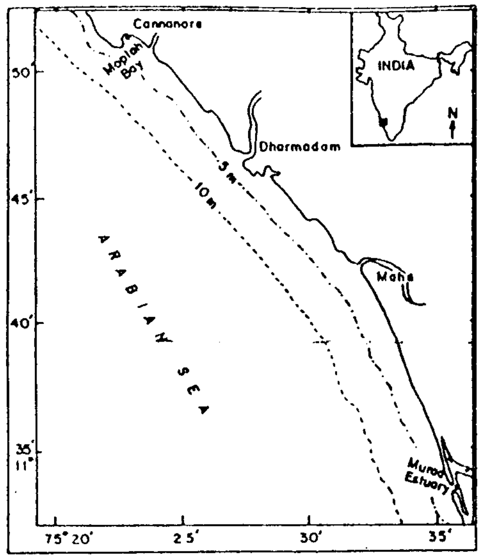

Fig.2 Map showing the Moplah bay and Murad estuary

MATERIALS AND METHODS

Principles

The principle behind the present methodology is to determine as quickly as possible the net rate of biochemical oxygen consumption / production per hr or per day in the tropical coastal waterbodies, using a much easier, less expensive and less complicated modified technique of 'Light and dark bottle oxygen estimation by Winkler's method', (normally used to determine the primary production) with an incubation of 2-3 hrs.

In this case, the difference in the titre values of water samples of the Light bottle (L) and the Initial bottle (I) per hr. (L-I) is considered to indicate the net rate of biochemical production (+ value) or consumption (- value) for the day time; and that of the Dark bottle (D) and Initial bottle (I) per hour ((D-I) is considered for the net rate of biochemical oxygen production (+ value) or consumption (- value) representing the night time. These values calculated in terms of ml O_2/l/hr are extrapolated for the 12 hrs of the day and the night time respectively. If possible, 24hrs. incubation is preferred.

Reagents

1) Standard potassium iodate / potassium dichromate solution (0.005N) : 0.1784 g of KIO_3 or 0.2452 g of $K_2Cr_2O_7$ is dissolved in 1 litre distilled water.
2) Sodium thiosulphate solution of (0.005 N) : 1.25g of $Na_2S_2O_3$ is dissolved in 1 litre distilled water. Fresh solution should be prepared every week and its normality standardised.
3) Winkler-A and B solutions and sulphuric acid (as per standard procedure of oxygen estimation given by Strickland and Parsons, 1972).

Standardisation and titration of water samples

As per the standard procedure followed to estimate dissovled oxygen in Winkler's method (Strickland and Parsons, 1972).

Calculation

Dissolved oxygen(ml/l) =

$$\frac{\text{Titre value} \times N \times 8 \times 1000 \times R}{100 \times 1.429}$$

where,

N = Normality of sodium thiosulphate solution

R = Correction factor=(1.01)

1.429 = wt. of 1 ml O_2 in mg

8	=	Eq. wt of oxygen
100	=	Volume of water sample titrated
1000	=	To convert the value per 1 litre

Commutation of the oxygen values thus obtained for the day time and night time [(L-I) + (D-I)] would give the net biochemical production (+ value) / consumption (- value) in the water sample per day (24 hrs). In other words, [(L-I) + (D-I)] per hr or day would give the net rate of oxygen gain (production) to the environment and [(I-L) + (I-D)] per hr or day would give the net rate of oxygen loss (consumption) from the environment in ml/l/hr or day.

In the analysis of time series data in a diurnal study or in the analysis of a series of water samples from an aquaculture farm, the net difference between [(L-I) + (D-I)] and [(I-L) + (I-D)] values per 24 hrs would give the net oxygen gain (production) or loss (consumption) of oxygen (ml/l) for the day. Plus and minus values indicate that the environment is in the reducing or oxidizing state respectively. For illustration, the diurnal data obtained from Moplah Bay and Murad estuarine mouth in Kerala (Fig.2) during 1991-92 in different months representing the peak premonsoon (March and April), southwest monsoon (July and August) and postmonsoon (December) seasons of the year are analysed.

RESULTS

Analysis of the data adopting this technique showed that, in the Moplah Bay (Table 1), the average rate of oxygen consumption was, in general, higher during December-April, (postmonsoon and premonsoon) while it was very less during July and August (southwest monsoon). The highest rate of oxygen consumption (0.073 ml/l/hr) was noticed in December while the highest production rate (0.0945 ml/l/hr) was recorded in April. The average net production of oxygen in the Moplah Bay was 0.708 ml/l/d (average of five months). In the case of Murad estuary, the average rate of oxygen consumption appeared to be more than production; and it was 0.200 ml/l/d (average of five months) (Table 2). Monthly mean values showed that the highest rate of oxygen production was 0.0491 ml/l/hr in August and that of oxygen consumption was 0.069 ml/l/hr during April.

DISCUSSION

As such, the procedures adopted to determine BOD and COD of the coastal waters are expensive, complicated and time consuming, which do not meet the immediate need at times of emergency; and they have several other drawbacks.

In the case of BOD and COD estimations, slight contamination leads to erroneous results; and the chemicals and apparatus contain fractions of organic matter which may lead to higher values (Boyd and Tucker, 1992).

In the case of BOD estimation, the extent of dilution is unknown for the water samples having different concentrations of organic matter which may lead to error and confusion; and the duration of five days for the analysis is fairly a very long period; and also it would be difficult to keep the water samples in 20°C continuously for five

Table 1 : Productive potential of dissolved oxygen (ml/l/hr) in the Moplah bay

(+) = Net gain/production; (-) = Net loss/utilization

Time	MARCH		APRIL		JULY		AUGUST		DECEMBER	
(hrs)	Prod.	Util.	Prod.	Util.	Prod.	Util.	Prod.	Util.	Prod.	Util.
0630	0.0010	0.1190	0.1617	0.0	0.0517	0.0	0.0341	0.0226	0.0010	0.1054
0830	0.0651	0.0887	0.0911	0.0	0.0333	0.02	0.1062	0.0	0.0739	0.0141
1030	0.0010	0.0377	0.0545	0.0542	0.0517	0.0	0.1825	0.0	0.0	0.1732
1230	0.0987	0.0985	0.0545	0.0542	0.0867	0.0	0.0357	0.0113	0.1135	0.0485
1430	0.1230	0.0	0.2039	0.0137	0.0767	0.0	0.0120	0.0117	0.0505	0.0505
1630	0.1184	0.0196	0.0009	0.1823	0.0933	0.0	0.0009	0.0158	0.0941	0.0462
Average	0.0679	0.0606	0.0945	0.0507	0.0655	0.0033	0.0619	0.0102	0.0555	0.0730
Net gain/ loss per hour	(+)0.0073		(+)0.0438		(+) 0.0622		(+) 0.0517		(-) 0.0175	
Seasonal	(+) 0.0255 ml/l/hr				(+) 0.0569 ml/l/hr				(-) 0,0175 ml/l/hr	
	Premonsoon				Southwest monsoon				Post monsoon	
average	(+) 0.612 ml/l/d				(+) 1.366 ml/l/d				(-) 0.420 ml/l/d	

Table 3 : Primary production in the Moplah bay and Murad estuary

Month	Season	Moplah bay		Murad estuary	
March	Premonsoon	0.694	0.610	0.211	0.221
April		0.526		0.232	
July	Southwest monsoon	0.560	0.447	0.004	0.108
August		0.334		0.212	
December	Postmonsoon	0.573	0.573	0.278	0.278
Average		0.537		0.187	

* All values in $gC/m^3/d$

days as per the procedure due to power cut and other technical difficulties; and it is meaningless to maintain the water samples in 20°C to estimate BOD in the tropical environment. Ultimately the estimated values do not give the real picture of BOD in the coastal aqualculture system, where the temperature may be different and likely to show variation from time to time and with seasons.

In the case of COD estimation, the values do not give the rate of COD per unit time. Further, it is believed that almost all organic compounds in water can be oxidized in the environment within such a short span of analysis time of the sample. Hence, the values obtained cannot be realistic; and it could be a potential estimate only. Moreover, the techniques that are applicable in temperate waters may not be applicable directly to our tropical environment. Further, the chemicals like mercuric sulphate and silver sulphate, involved in the COD estimation are costly and the procedure becomes very cumbersome.

Whereas, in the case of the present technique, it is less expensive, less complicated and the result can be obtained as consumption / production rate per unit time, on the same day of sampling which would help the aquaculturist or the scientists concerned to know the extent to which the water in the system is in the oxidizing or reducing state; and this would help them to take necessary step to meet the immediate need at times of emergency.

The results of the application of the present technique in the shallow intertidal surf zone of the Moplah Bay and in the Murad estuary revealed that the rate of oxygen production / consumption in water was changing from hour to hour in the diurnal observation (Tables 1, 2) due to tidal influence and connected physico-chemical processes. In the Moplah Bay, the rate of oxygen production was in

Table 4 : The net rate of oxygen production / consumption and primary production in the Moplah bay

(+ = Production; - = Consumption)

Month	O_2 Production / Consumption ($mgO_2/m^3/hr$)	Average NPP* ($mgC/m^3/hr$)
March	10.4	57.8
April	62.6	43.8
July	88.9	46.7
August	73.9	27.8
December	-25.0	47.75

* NPP = Net Primary Production

general, higher than the rate of oxygen consumption (Table 1), thus providing a healthy environment with moderate primary production (Table 3), while the Murad estuary proved to be less fertile in the case of oxygen production / consumption (Table 2) and in primary production (Table 3) as compared to the Moplah Bay.

In the Moplah Bay, the very low rate of oxygen consumption noticed during July and August indicated that the oxygen demand from the microbial organisms and from other biochemical processes was very less during the southwest monsoon season; while during December - April (postmonsoon and premonsoon), although the rate of oxygen consumption was more, this was compensated by the rate of oxygen production, especially with high production during April (Table 1). However, the rate of increase in oxygen production did not show any direct relation with increase in the rate of photosynthetic production in the different months at the Moplah Bay (Table 4) which indicated that the contribution to the rate of oxygen production in water is not only from the photosynthetic production, but also considerably from the other biochemical reduction processes apart from the biochemical oxidation already undergoing in the aquatic systems.

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