

TCO₂ - O₂ Correlation in the Central Arabian Sea

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Linear relationship exists between total CO₂ (TCO₂) and observed dissolved oxygen in the central Arabian Sea, which agrees well with the organic decomposition model of Redfield, Ketchum and Richards (*The Sea* edited by M.N. Hill, Vol. 2, 1963, P 26). Ratios of $\Delta C/\Delta O$ obtained for 13 stations in this region are in good agreement with the theoretical value. Processes other than oxidations effecting TCO₂ are considered for correction to obtain the linear correlation.

It has been shown that Redfield, Ketchum and Richards model¹ (RKR model) can predict variations in phosphorus, nitrogen, carbon and oxygen in the sea due to the oxidation processes. This model has been applied to study TCO₂ - O₂ relations in the northeastern² and eastern Pacific³ oceans and few Meteor data on equatorial Indian Ocean^{4,5}. Pytkowicz and Kester⁶ and Pytkowicz⁷ have considered this model for open system and shown that apparent oxygen utilization (AOU) and preformed quantities of nutrients were in linear combination in different water types composing a water mass.

In the present communication, the relationship TCO₂ - O₂ in the central Arabian Sea and the use of RKR model as modified by Culberson and Pytkowicz³ for compensating the changes in TCO₂ due to non-oxidative processes have been discussed.

Samples were collected from 13 stations from the central Arabian sea during 103 cruise of *RV Gaveshani*

(Feb. 1982). Salinity was measured by Autosal 8400 salinometer with a precision of 0.003×10^{-3} . Dissolved O₂ was determined by the Winkler method as described by Strickland and Parsons⁸. pH was measured by Systronics digital pH meter 335 with a precision of 0.01 unit. O₂ solubility data of Green and Carritt⁹ were used to compute AOU. Total alkalinity (TA) was measured by the method of Anderson and Robinson¹⁰ as modified by Culberson *et al.*¹¹. TCO₂ was calculated by the equations given by Takahashi *et al.*¹². Apparent dissociation constants of carbonic acid and boric acid and their pressure derivatives were computed from Lyman's data¹³ and the equations of Culberson and Pytkowicz¹⁴. A boron/chlorinity ratio of 0.237 was used for calculating total boron¹⁵ (TB).

Calculated quantities from original data for st 2350 (chosen as representative to demonstrate results) are given in Table 1. In the present study, values of TA are consistently higher than Meteor data⁵. They are

Table 1—Data Collected at St 2350

Depth (m)	T (°C)	S ($\times 10^{-3}$)	O ₂ ($\mu\text{g-at.kg}^{-1}$)	AOU ($\mu\text{g-at.kg}^{-1}$)	pH (25°C)	TA (m eq kg ⁻¹)
1	26.00	36.571	469	-6	8.19	2.562
24	25.97	35.062	380	160	8.20	2.564
48	25.81	35.653	419	319	8.22	2.551
72	23.38	36.291	123	380	8.12	2.532
96	20.55	35.824	40	436	7.97	2.560
136	17.07	35.783	22	495	7.83	2.573
191	15.36	35.560	20	505	7.76	2.590
280	12.23	35.453	29	535	7.70	2.598
374	13.17	35.420	22	526	7.70	2.603
472	11.57	35.410	29	520	7.68	2.609
560	12.49	35.491	25	531	7.69	2.600
741	10.03	35.503	34	554	7.70	2.623
912	9.37	35.416	40	558	7.67	2.645
1133	7.82	35.413	50	567	7.70	2.672
1413	5.89	34.242	80	567	7.69	2.693
1903	3.81	34.973	129	551	7.70	2.740
2384	2.35	35.010	169	539	7.72	2.753
2864	1.88	35.001	185	531	7.72	2.768
3372	1.75	35.002	190	525	7.79	2.773

however, in fair agreement with the earlier observations¹⁶. For all 13 stations, values of TA varied within 8% from surface to 3000 m.

Concentration of TCO₂ for the linear combination is given by²,

$$\text{TCO}_2 = \text{Co} + \Delta \text{Cb} + \Delta \text{Ca} \quad \dots (1)$$

where Co is preformed TCO₂ and is the function of temperature, salinity and initial partial pressure of CO₂. Δ Cb is change in TCO₂ due to biological oxidation and is equal to b(AOU), where $b = 106/276 = 0.384$, a ratio of carbon and oxygen atoms and Δ Ca is the contribution by non-oxidative phenomena.

Like Culberson and Pytkowicz³, vertical variation in preformed quantities have been taken into consideration. Since, the contributions due to non-oxidation phenomena are the variation in salinity, alkalinity and preformed CO₂, one should consider all these changes.

At depth of central Arabian Sea, salinity is 35×10^{-3} and alkalinity is $2.771 \text{ meq kg}^{-1}$ of seawater. According to Postma¹⁷, one can write $\text{TCO}'_2 = \text{TCO}_2 (35/S) + 0.5 [2.771 - \text{T Am} (35/S)]$

$$\dots (2)$$

where TCO'₂ is the concentration of TCO₂ after the correction for alkalinity and salinity and T Am is the measured alkalinity.

Combining Eq. 1 and 2

$$\text{TCO}_2 = \text{Co} (35/S) + \text{Cb} (35/S) + 0.5 [2.771 - 35 (\text{T Ao}/S)] \quad \dots (3)$$

where T Ao is the initial alkalinity. It is clear from Eq. 3 that if one plots TCO'₂ against AOU, a straight line with a slope 0.384 should be expected.

In Fig. 1, plots of TCO₂ against AOU (normalized) ($\text{AOU}_{\text{normalized}} = \frac{\text{AOU} \times 35}{S}$) are shown for the st 2350. TCO'₂ plots are not linear at all stations. However, in TCO'₂ plot, the curvature of TCO₂ plot is reduced, but not to the extent as described by RKR model.

Uptil now, we have neglected any correction as regards to Co and/or T Ao/S with depth. Co, with respect to pressure was computed by the method described elsewhere³. Specific alkalinities of surface water in this region are reasonably constant at 0.120 to 0.126. The initial partial pressure of CO₂ i.e. PCO₂ and specific alkalinity used in the calculations were $330 \times 10^{-6} \text{ atm}$ and 0.125 respectively.

TCO'₂ (corrected TCO₂ for salinity, alkalinity and preformed CO₂) can now be written as

$$\text{TCO}'_2 = \text{TCG}'_2 + [2.16 - \text{Co}' (35/S)] \quad \dots (4)$$

and

$$\text{TCO}'_2 = 2.16 + (\text{Co} - \text{Co}') (35/S) + (106/276)\text{AOU} (35/S) + 0.5 [2.771 - 35 (\text{T Ao}/S)] \quad \dots (5)$$

where Co is the initial value of TCO₂ which depends on initial partial pressure of CO₂ (PCO₂) and on specific alkalinity. Co' is the value of TCO₂, calculated at constant PCO₂ and specific alkalinity.

In this equation, the plots of TCO'₂ against AOU (normalized) should be a straight line provided the Co - Co' and T Ao/S are constant.

TCO'₂ plot with slope 0.394 (Fig. 1) is straight line at st 2350. The ratio (Δ C/Δ O) for all the stations are listed in Table 2 individually. Since TCO₂ - AOU (normalized) diagrams are the same for other stations, they are not included here.

The slopes vary between 0.389 and 0.401. The average value (0.395 ± 0.010) obtained presently is 2.9% higher than the theoretical value (0.384). Oceanographic conditions regulating this relationship

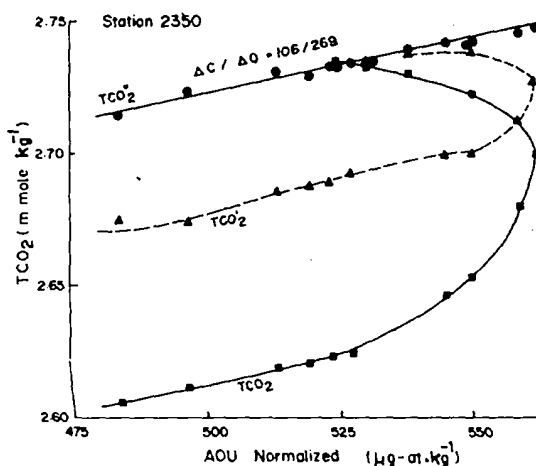


Fig. 1--TCO₂ - AOU relationship at st 2350

Table 2 - Calculated Slopes (Δ C/Δ O) at Various Stations in Central Arabian Sea

Sts	Locations		Slope*
	Lat. (N)	Long. (E)	
2338	15°00.0'	70°30.0'	0.391
2342	15°05.0'	68°25.0'	0.396
2346	15°05.0'	66°27.0'	0.390
2350	15°00.0'	64°30.0'	0.394
2354	15°00.0'	62°00.0'	0.389
2356	15°00.5'	61°30.0'	0.399
2358	15°01.5'	60°27.0'	0.399
2360	15°00.0'	59°30.0'	0.393
2362	15°02.2'	58°20.3'	0.398
2367	16°40.0'	60°27.0'	0.395
2371	18°59.8'	62°29.0'	0.399
2373	19°00.0'	63°40.0'	0.401
2375	18°58.0'	64°30.0'	0.390

*Average 0.395

vary at different areas. Culberson⁴ reported vary low values (0.361 ± 0.012) for equatorial Indian Ocean. Considering the uncertainties involved in the measurements, present value is in fair agreement with theoretical value. At all stations, the curves of TCO_2 versus AOU are linear between 150 and 3000 m. The average intercept value 2.569 is within the 2 sigma precision, and the correlation coefficient is 0.993.

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