

Studies on Carbon Dioxide System in Central Arabian Sea

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Data on pH and total alkalinity have been utilised in the study of carbon dioxide and its species in Central Arabian Sea. Total carbon dioxide and partial pressure of carbon dioxide remain fairly constant in the upper layers but increase significantly with depth. Bicarbonate ion is quantitatively the major component of the carbon dioxide system. The observed vertical distributions are discussed in terms of biological and geochemical processes in the sea.

CO₂ system in the sea plays a significant role in biological and chemical processes. While there is a biological uptake of CO₂ in the upper euphotic zone in the sea, CO₂ is generated by oxidation of organic matter in subsurface layers. Active exchange of CO₂ between sea and atmosphere and weathering processes regulate the equilibria among the CO₂ species and are important factors to be considered in studies on the CO₂ system in the sea. Singbal and Reddy¹ studied the distribution of CO₂ species in this system. The present work deals with the distribution of CO₂ and its species in the central Arabian Sea.

Niskin bottles or CTD rosettes were used for collection of water samples during 103 cruise of *R/V Gaveshni* (Feb. 1982) in the central Arabian Sea (lat. 15°-20° N, long. 58°-71° E). Temperature, salinity, total alkalinity (TA), pH at 25°C (pH₂₅), dissolved O₂ were estimated as reported earlier². CO₂ and its species, viz. total CO₂ (TCO₂), partial pressure of CO₂ (PCO₂), bicarbonate (HCO₃⁻), and carbonate (CO₃²⁻) ions and apparent oxygen utilization (AOU) were computed^{1,2}. The pH *in situ* was computed based on data on pressure coefficients given by Culberson and Pytkowicz³. The concentration scale in the computations was per kilogram of seawater. Measurements in volumetric units were converted into kilogram using equation proposed by Millero *et al.*⁴ Uncertainties of 0.01 meq.kg⁻¹ and 0.01 unit in total alkalinity and pH were associated respectively with the errors of 0.004 m mol.kg⁻¹, 0.002 m mol.kg⁻¹, 30 × 10⁻⁶ atm, 0.002 m mol.kg⁻¹ in HCO₃⁻, CO₃²⁻, PCO₂ and TCO₂.

Fig. 1 presents the vertical profiles of average values of temperature, salinity, pH₂₅ and total alkalinity. pH₂₅ decreases in deep waters and it is possibly due to decomposition of organic matter.

Vertical distributions of various CO₂ species and AOU are given in Fig. 2. TCO₂ increases up to 150 m depth and decreases in intermediate waters. In deep

waters (below 1500 m), it further increases very slowly indicating that CO₂ though continuously being withdrawn from surface waters for biosynthesis it accumulates in deep waters through oxidation of sinking organic matter. The slow increase in TCO₂ in the upper layer is apparently due to photosynthesis since AOU (Fig. 2) does not change in this region. In deep waters, the increase of TCO₂ depends on the higher TA. Present values of TA are higher by 0.3 to 0.4 meq.kg⁻¹ than Atlantic and Pacific Ocean

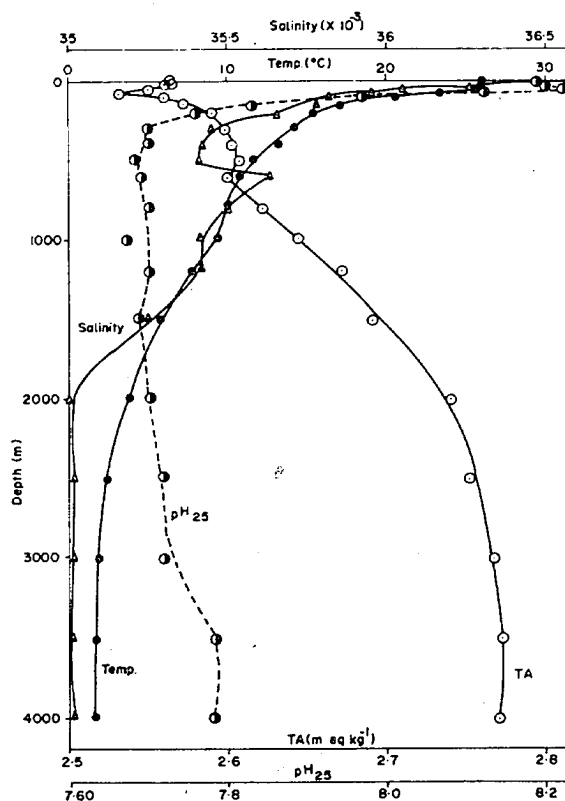


Fig. 1.—Vertical profiles of salinity, temperature pH₂₅ and total alkalinity [values represent average of samples collected at 13 stations].

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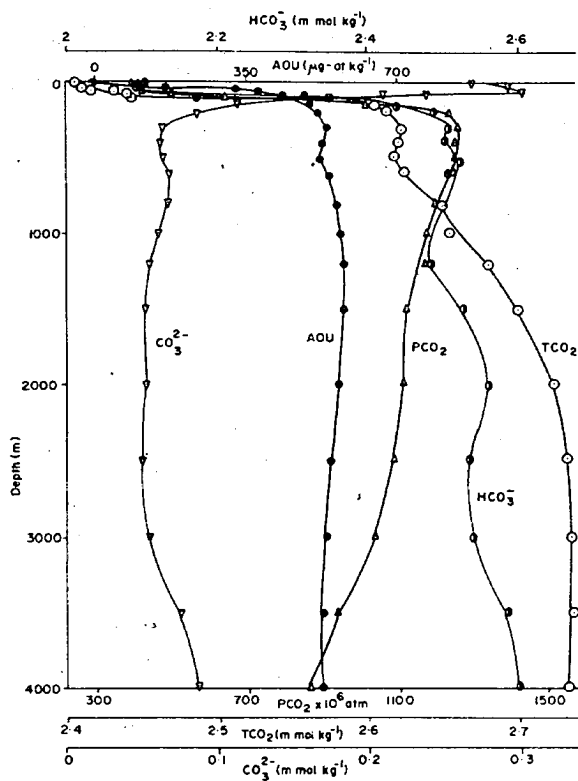


Fig. 2—Vertical distribution of TCO₂, PCO₂, AOU, HCO₃⁻ and CO₃²⁻ species [values represent average of samples collected at 13 stations]

waters⁵. This indicates increased solubility of carbonate solution, which in turn increases the TCO₂. These agree well with our earlier observations⁶ and are further supported by studies² based on the organic decomposition model of Redfield *et al.*⁷ where TCO₂ in intermediate water is calculated by the linear combination of terms originating from surface and deep waters. The average ratio $\Delta C/\Delta O$ obtained 0.399 ± 0.01 is in agreement with theoretical slope (0.384).

AOU increases below 100m indicating increased oxidation of organic matter and decreases below

2000 m depth. This decrease in AOU, viz. increasing O₂ along with lower salinity, temperature and pH (Fig. 1) suggests that water below 2000m is of Antarctic circumpolar origin which has high O₂ values.

The pressure exerted due to the dissolution of CO₂ in seawater (PCO₂) is very low but varies widely in intermediate and deep waters. In surface waters, PCO₂ increases gradually (within 30×10^{-6} atm). These low values of PCO₂ in the euphotic zone are presumably due to a high rate of photosynthesis. At about 200 m depth, increase in PCO₂ is accompanied by decrease in pH value at this depth indicating effects of biological oxidation. From 800 m to deep waters, PCO₂ decreases steadily.

HCO₃⁻ appears to be the major species in the CO₂ system and follows the same trend as TCO₂ (Fig. 2). The surface water has about 2.16 mol.kg^{-1} of HCO₃⁻ which increases by 0.38 mol.kg^{-1} in deep waters.

Levels of CO₃²⁻ ions are low throughout being 0.24 mol.kg^{-1} at the surface and the level decrease by 30% in deep waters. In the upper 75 m concentration of CO₃²⁻ ion reaches maximum and then decreases in deep waters. These changes are similar to those observed in pH values in surface and deep waters.

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References

- 1 Singbal S Y S & Reddy C V G, *Indian J Mar Sci.* 12 (1983) 239.
- 2 Kumar A & Singbal S Y S, *Indian J Mar Sci.* 13 (1984) 136.
- 3 Culberson C & Pytkowicz R M, *Limnol Oceanogr.* 13 (1968) 403.
- 4 Millero F J, *Geochim Cosmochim Acta.* 43 (1979) 1651.
- 5 Shiller A M & Gieskes J M, *J Geophys Res.* 85 (1980) 2719.
- 6 Anonymous. Initial report and data file on INS *Darshak* Oceanographic expedition, National Institute of Oceanography, 1974.
- 7 Redfield A C, Ketchum B H & Richards F A, in *The sea*, Vol. 2, edited by M N Hill (Interscience, New York) 1963, 26.