

Some aspects of nutrient chemistry of the Caribbean Sea

A. RAJENDRAN,¹ M. DILEEP KUMAR,¹ AHMAD A. KHAN,² D. KNIGHT,³ AVIS O'REILLY,⁴ I. CHANG YEN,⁵
A. B. WAGH,¹ AND B. N. DESAI¹

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Chemical oceanographic studies were conducted at 45 stations in the Caribbean Sea, covering both nearshore and offshore areas. The concentrations of oxygen in the upper mixed layers varied between 180 and 220 $\mu\text{mol} \cdot \text{dm}^{-3}$ and the subsurface waters showed a decrease up to 110 $\mu\text{mol} \cdot \text{dm}^{-3}$ at around 400 m. Within the euphotic zone considerable amounts of oxygen (30-60 $\mu\text{mol} \cdot \text{dm}^{-3}$) were utilized for organic matter degradation, even within the euphotic zone. Two nitrate maxima, one representing nitrite excretion/organic matter oxidation and another due to nitrate reduction, were observed. Phosphate and nitrate levels were low in the upper 60 m and showed an increase with depth due to regeneration processes. Salinity - nutrient oxygen relations and silicate and density relations revealed surface, subtropical subsurface and subantarctic water mass signatures in the upper 500 m.

L'on a effectué des études océanographiques chimiques dans 45 centrales dans la Mer des Caraïbes, comprenant des régions à la fois près du littoral et loin du littoral. Les concentrations d'oxygène dans les couches mélangées supérieures variaient entre 180 et 220 $\mu\text{mol} \cdot \text{dm}^{-3}$ et les eaux au-dessous de la surface ont révélé une diminution jusqu'à 110 $\mu\text{mol} \cdot \text{dm}^{-3}$ à 400 mètres environ. A l'intérieur de la zone euphotique l'on a utilisé des quantités importantes d'oxygène (30-60 $\mu\text{mol} \cdot \text{dm}^{-3}$) pour la dégradation de matières organiques, même à l'intérieur de la zone euphotique. L'on a étudié deux maxima de nitrate, l'un qui représente l'excrétion de nitrite/l'oxydation de matières organiques et un autre dû à la réduction de nitrates. Les niveaux de phosphate et de nitrate s'avéraient bas dans les 60 mètres supérieurs et démontraient une augmentation selon la profondeur due aux processus de régénération. La salinité - des relations d'oxygène nutritif et des relations de silicate et de densité à découvert des signatures à la surface, au-dessous de la surface subtropicale et des masses d'eau subantarctique dans les 500 mètres supérieurs.

Se efectuó estudios oceanográficos químicos en 45 centrales en el Mar Caribe comprendiendo regiones cerca de la costa e igualmente lejos de la costa. Las concentraciones de oxígeno en los estratos mezclados superiores variaban entre 180 y 220 $\mu\text{mol} \cdot \text{dm}^{-3}$ y las aguas por debajo de la superficie desvelaron una disminución hasta 100 $\mu\text{mol} \cdot \text{dm}^{-3}$ en cerca de 400 metros. Dentro de la zona eufótica se utilizó cantidades importantes de oxígeno (30-60 $\mu\text{mol} \cdot \text{dm}^{-3}$) para la degradación de sustancias orgánicas, aún dentro de la zona eufótica. Se observó dos maxima de nitratos, uno que representa la excreción de nitritos/la oxidación de sustancias orgánicas y otro que es debido a la reducción de nitratos. Los niveles de fosfato y de nitratos resultaban bajos en los 60 metros superiores y demostraban un aumento según la hondura debido a los procesos de regeneración. La salinidad - relaciones de oxígeno nutritivo y relaciones de silicato y de densidad descubrió firmas en la superficie, por debajo de la superficie subtropical y masas de agua subantártica en los 500 metros superiores.

Introduction

The Caribbean Sea and the Gulf of Mexico are regions of complex topography linking North America and South America. The Caribbean Sea contains five large physiographic units. These are the Yucatan Basin, the Cayman

Trough, the Colombia Basin, the Venezuela Basin, and the Grenada Trough and also several smaller deep basins. All are separated by irregular structural ridges and bordered by flat continental shelves and bank tops.

The Caribbean Sea measures about 2.64 million km^2 in the south-western part of the north Atlantic Ocean. The eastern boundary consists of the Antillean chain of islands which play a very significant role in determining water circulation of this region (Gordon 1966). Concerning water balance, the region is negatively balanced having an evaporation rate higher by

¹National Institute of Oceanography, Dona Paula, Goa-403 004, India.

²Institute of Marine Affairs, Trinidad and Tobago, West Indies.

³National Resources Conservation Department, Kingston, Jamaica, West Indies.

⁴Chemistry and Food Technology Division, Ministry of Agriculture, Fisheries, Lands & Housing, Dunbar, Antigua, West Indies.

⁵Department of Chemistry, The University of the West Indies, St Augustine, Trinidad, West Indies.

104 cm · T⁻¹ than the precipitation (Etter et al. 1987). Though river input is considerable, this cannot compensate for the negative balance in water (Etter et al. 1987). Nutrients play an important role in the regulation of biological production and may also be used to identify or characterize masses in the oceans (Broecker and Peng 1982).

Certain aspects of nutrient chemistry with reference to circulation and biological productivity, employing data collected between 14th April and 24th May, 1990 during the four legs of the Caribbean Oceanographic Resources Exploration (CORE) cruise are examined in this study.

Materials and Methods

Water samples were either collected and analysed or parameters recorded at 45 sampling stations along each of the four legs of the CORE cruise in the Caribbean Sea (Map 1, p. 4). The parameters studied were oxygen, pH, ammonia, nitrate, nitrite, phosphate, and silicate. Oxygen levels were determined by Winkler titration, pH by a Beckman pH meter

using a combination pH electrode. NBS buffers were used for electrode calibration. Ammonia was measured through the indophenol blue method according to Grasshoff et al. (1983). Measurements were made on a Bausch and Lomb spectrophotometer 1201. Nitrate, nitrite, phosphate, and silicate were determined on a Skalar autoanalyser system. Samples were supplied to the system through a Skalar SA 1000 autosampler.

Results and Discussion

In the surface and superficial layers nutrient levels were generally low but increased with depth, especially below the euphotic zone/thermocline. The thermocline varied between depths of 50 m and 120 m. Nutrients increased below this physicochemical barrier. Figures 1a and 1b show typical nutrient profiles for Station 39 (Leg IV, Lat. 10°34' N, Long. 59°31' W). Nitrate, phosphate, and silicate were relatively low near the sea surface owing to rapid turnover of organic matter. Below 30-m depths the concentrations increased as a result of the decomposition of the biological material.

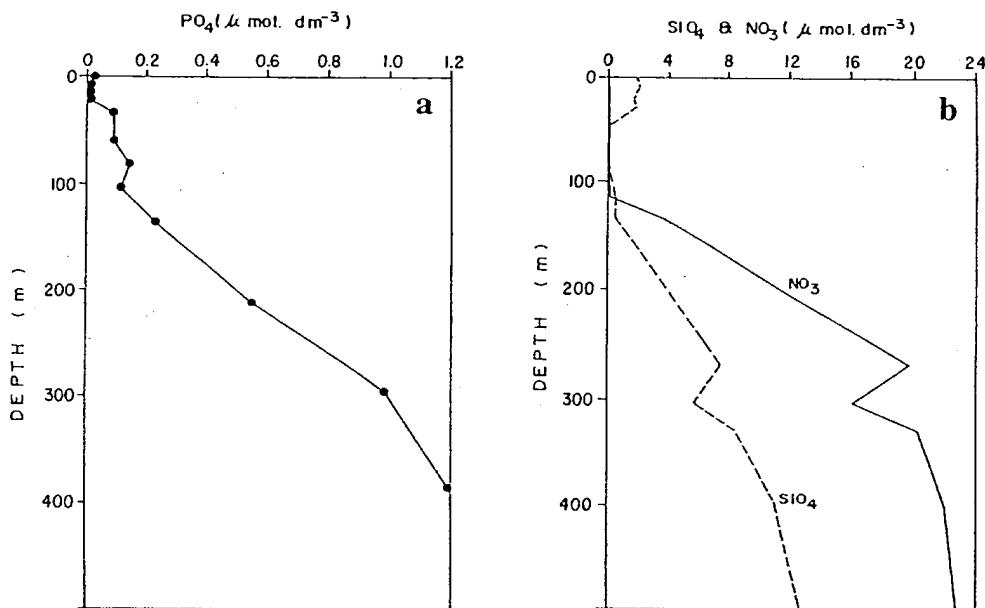


FIG. 1. Typical vertical profiles of nutrients in the Caribbean Sea (Station 39, Leg IV); (a) phosphate and (b) nitrate and silicate.

Distribution of nitrites showed two maxima, one at 42 m ($0.2 \mu\text{mol} \cdot \text{dm}^{-3}$) and another between 340 and 420 m (Fig. 2). At depths between 42 m and 110 m nitrates were not detected. An interesting feature observed at Station 1 (Leg I, Lat. $17^{\circ}09' \text{ N}$, Long $87^{\circ}07' \text{ W}$) was that there seemed to be an occurrence of enormous nitrate reduction resulting in the secondary production of nitrite in the depth range 250–500-m, corresponding to the decrease in oxygen levels (Fig. 2). Nitrite occurred at significant concentrations ($0.02 \mu\text{mol} \cdot \text{dm}^{-3}$) and an obvious decrease in oxygen concentration (from 200 to $110 \mu\text{mol} \cdot \text{dm}^{-3}$) at these depths suggests the possible occurrence of denitrification. Secondary nitrite maxima were also observed at stations 3, 4, and 7 (Leg I). The primary nitrite maximum occurred near the thermocline region (Fig. 2) coinciding with higher oxygen concentration. This suggests that there might be nitrite excretion from phytoplankton due to higher photosynthetic activity or that it might be due to nitrification processes.

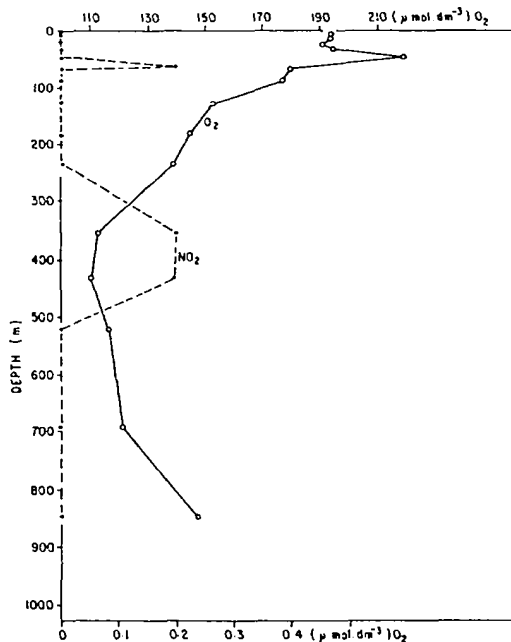


FIG. 2. Vertical profiles of oxygen and nitrite depicting the occurrence of secondary nitrite production at Station 1, Leg I.

Oxygen in the upper layers varied between 180 and $220 \mu\text{mol} \cdot \text{dm}^{-3}$ while in subsurface layers it decreased to $110 \mu\text{mol} \cdot \text{dm}^{-3}$ at about 400 m. At a few stations off Belize, somewhat higher oxygen concentrations were found at 600-m depths, higher than those at levels above and below this. The circulation pattern in the Caribbean Sea is east to west. This relatively high oxygen with low salinity indicates the flow of subantarctic intermediate water through the Caribbean before outflowing through the Yucatan Basin in the west (Gordon 1966). A significant observation is that the low nutrient levels observed at Station 27 (Leg III) off St Lucia at a 300-m depth (Fig. 3a and 3b) was associated with the low oxygen level of $128 \mu\text{mol} \cdot \text{dm}^{-3}$ (compared to what is expected at this depth). The flow from the Atlantic into the Caribbean Sea mostly occurs south and north of St Lucia. The station occupied was situated south-west of St Lucia and hence low nutrient and oxygen levels at 300 m at this station were probably the result of a subsurface water mass which originated either from off-shore Guyana or the north equatorial region.

Relationships between temperature and chemical variables may be used to identify various water layers. The cluster of points having highest oxygen concentrations associated with high temperature indicate surface water layers (Fig. 4a and 4b). Oxygen levels decrease in subsurface layers because of organic matter decomposition. The distinction of surface and subsurface water masses becomes more clear in Fig. 5a and 5b which are plots of salinity and nitrate. Surface water masses have low nitrate concentrations and a wide range of variation in salinity between 33 and 35%. The low salinities are due to river influx, especially of the Orinoco River, which is particularly important off north-eastern South America. However, the subsurface layers significantly exhibit decreasing salinity but increasing nitrate. An important feature is that at salinities below 33.5×10^{-3} the nitrate has a negative relationship with salinity (Fig. 5b) that suggests appreciable nitrate inputs from rivers of this region namely off Venezuela and Guyana. These water masses are confirmed by tracing them through silicate relationships with density (Fig. 6). Silicate in

general increases with depth because of the dissolution of sinking skeletal material from surface layers. Surface water masses and subsurface subtropical water masses are evident where the latter shows rapid increase in silicate concentrations. The influence of rivers on surface silicate distribution is conspicuous in Fig. 6, where silicate levels reach a maximum of $9 \mu\text{mol} \cdot \text{dm}^{-3}$ in surface layers.

Figures 7 and 8 show biochemical relationships observed in the Caribbean Sea. In these figures

apparent oxygen utilization (AOU) was related to the phosphate and nitrate concentrations. AOU is defined as the oxygen solubility, when the sample was at sea surface in contact with the atmosphere at the temperature of the sample, minus the oxygen observed. AOU is an indicator of oxygen utilized for the decomposition of biological material. Significantly, even within the euphotic zone, oxygen is utilized to a range of 30 to $60 \mu\text{mol} \cdot \text{dm}^{-3}$ for biogenic material decomposition. This also indicates that the production of oxygen,

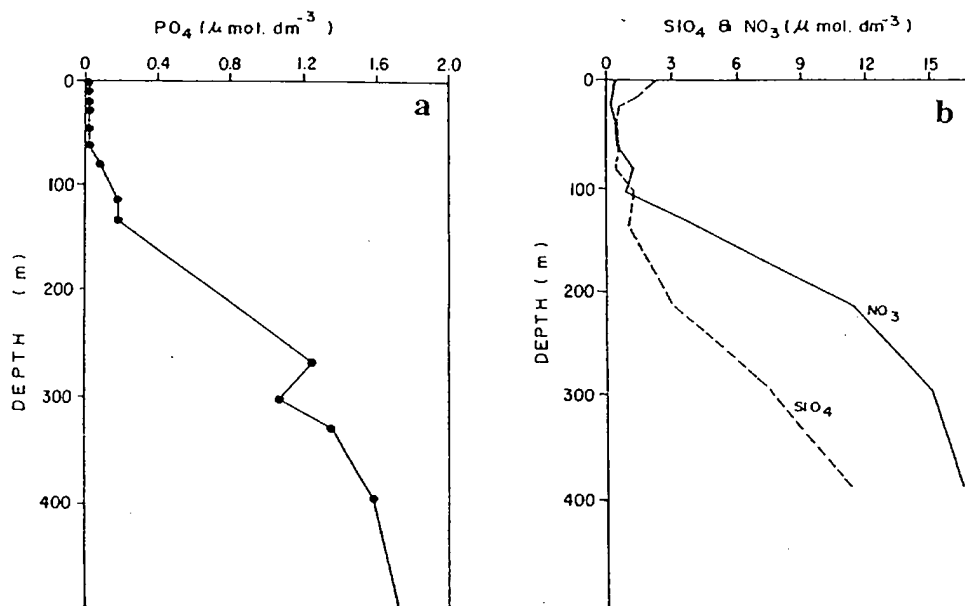


FIG. 3. Occurrence of a nutrient minima around 300 m at Station 27, Leg III; (a) phosphate and (b) nitrate and silicate.

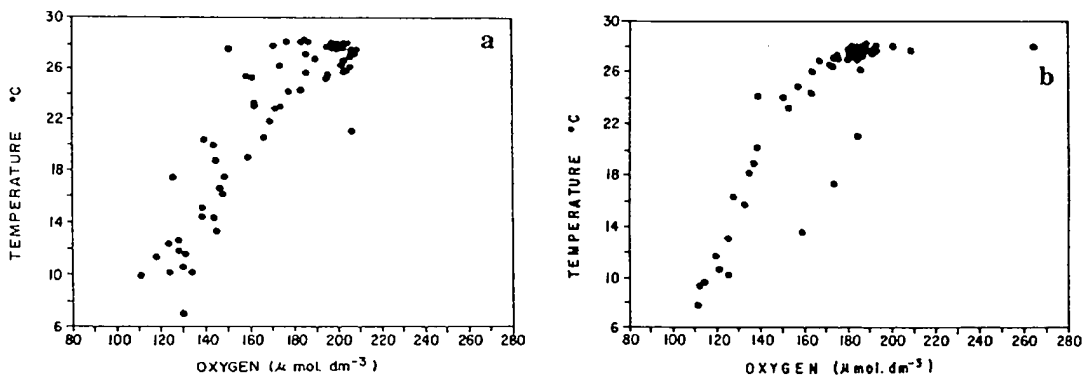


FIG. 4. Relationship between temperature and oxygen. (a) Leg III and (b) Leg IV.

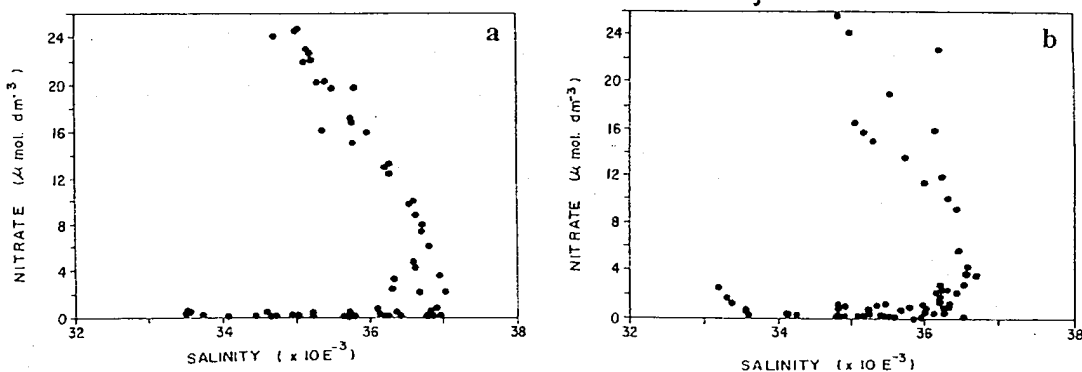


FIG. 5. Relationship between salinity and nitrate. (a) Leg III and (b) Leg IV.

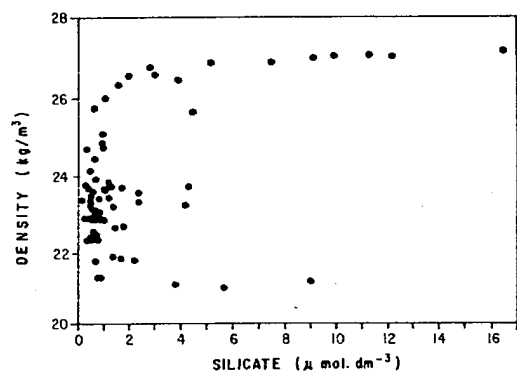


FIG. 6. Relationship between density and silicate.

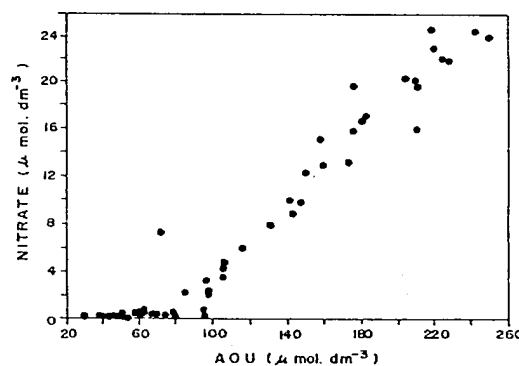


FIG. 8. AOU relationship with nitrate in the Caribbean Sea, Leg III.

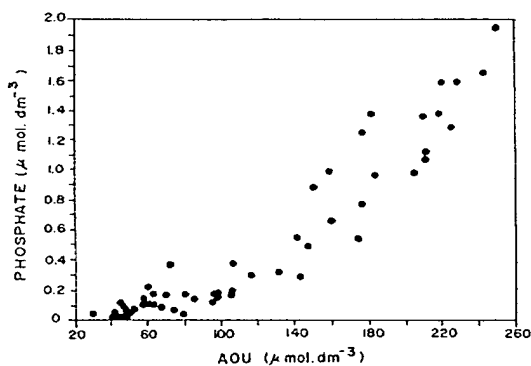


FIG. 7. AOU relationship with phosphate in the Caribbean Sea, Leg III.

probably due to low photosynthetic activity, seems to be negligible. Figures 7 and 8 depict

positive relations between AOU and nutrients. As the oxygen is consumed during the regeneration process the nutrients are released to sea-water. These relationships show that although there is a net oxidation of organic matter from the surface to the depth sampled, there is always a higher rate of oxidation in the depth range between 130 m and 300 m. From the observed relationship in Figs. 7 and 8, the biochemical relationship established in 137.5 : 10.1 : 1 for AOU : NO₃ : PO₄. These values are in the range reported in general for oceanic waters but deviate from the actual planktonic ratios of 106 : 15 : 1 given by Redfield et al. (1963).

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