Bull. Environ. Contam. Toxicol. (1997) 59:486-491

Bulletin of Environmental Contamination and Toxicology

Detergents and Orthophosphates Inputs from Urban Discharges to Chetumal Bay, Quintana Roo, Mexico

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Received: 20 October 1996/Accepted: 1 June 1997

A high proportion of phosphates arise of domestic sewage and are disposed directly into the aquatic environment (Barroin, 1992), which in turn induces growth and reproduction of green algae (Follmi, 1994). A number of studies have investigated the effect of anthropogenic phosphorus and other nutrients in aquatic ecosystems (Patrick & Khalid, 1974; Sales *et al.,* 1987; Hinga, 1990; Salas & Martino, 1991).

Chetumal Bay is located in southern Quintana Roo, in the Yucatan Peninsula of Mexico. The bay is 67 km long and 12 km at the middle; with a total area of 1100 km^2 (Delgado & Chavira, 1984; Flores & Cano, 1990). The bay presents estuarine characteristics due to the Rio Hondo's influence. Its average salinity is 14‰, considered as a hyposaline system (Gasca *et al.,* 1994) with low productivity (Gasca & Castellanos, 1993). Because of its low depth (3.28 m average), water movement is determined mainly by the predominant trade winds (E and SE) with a speed of 3m sec^{-1} on average (Chavira *et al.,* 1992).

Chetumal is located on the West coast of the bay, near the mouth of Rio Hondo. The urban zone borders almost 10 km of coast line. The wastewaters from the oldest zone of the city are channeled toward the bay through the pluvial sewer system (Fig. 1). We calculated an average discharge of organic waste of 200 m^3 per day into the bay. This paper examines the presence of orthophosphates from anthropogenic loading in the water column of Chetumal Bay and their influence on chlorophyll *a* concentrations.

MATERIALS AND METHODS

Nine stations were chosen, seven with constant outflow and the other two without discharges. Water samples were collected monthly from September, 1993 to June, 1994. Samples were taken at the mouth of each discharge and at 1, 50 and 100 m away (Fig. 1).

All parameters were determined monthly except dissolved oxygen during October, November and February. Dissolved oxygen (DO) was determined by the standard Winkler procedure (Strickland & Parsons, 1972) and pH *in situ* using Corning Check-mate type 90.

Detergents were measured using the colorimetric method of methylene blue active subtances (MBAS); orthophosphates (PO_4^{3-}) with the colorimetric method of a phospho-molybdate complex. Nitrite (NO_2) with the colorimetric method of Griess's reaction and nitrate (NO_3) with the colorimetric method of Cd-Cu reduction (APHA - AWWA - WPCF, 1985; Strickland & Parsons, 1972); we refered to nitrogen as NO_3 plus NO_2. Chlorophyll *a* was filtered through Millipore 0.45 µm membrane filters and extracted with acetone 90% (SCOR - UNESCO, 1980). All readings were obtained with a Bauch & Lomb

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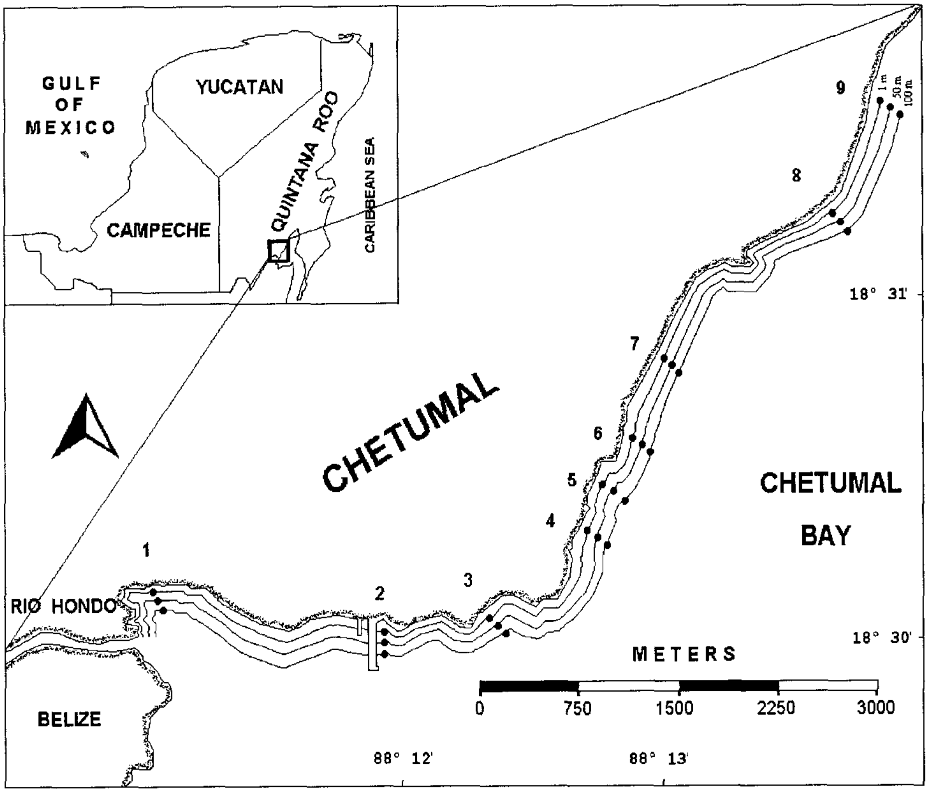

Figure 1. Study area and sampling stations

spectrophotometer type 1001.

Results were submitted to three-way ANOVA analysis (distance, station and month) and Tukey comparison multiple test ($p < 0.05$). In order to determine the presence of any effect of detergents on nutrients and chlorophyll *a,* linear regression analysis ($p < 0.05$) was used. Data were transformed to Ln (x)+1.

RESULTS AND DISCUSSION

The highest concentrations of detergents were registered in discharges, with a range from 0.08 to 2.86 mg l^{-1} decreasing when increasing distance from shoreline (Fig. 2). The ANOVA test indicated that detergent concentrations were significantly elevated in discharges and at 1 m, compared to those obtained at 50 and 100 m ($p < 0.001$).

Station 3 and 9 presented the lowest average detergent values (Tukey test), since they were not located near discharges (Fig. 3a). During April, May and June the flow of residual waters in some sectors of the city were channeled toward an oxidation lagoon. This was reflected in significantly lower detergents' values compared with other months (Fig. 3b). PO_4^{3-} values showed a similar trend to the detergents in relation to distance as well as in stations and months (Figs. 3a, 3b). Because the significant correlation between both parameters ($r = 0.88$, $p < 0.00001$), detergents are considered the main source of PO_4^{3-} in the urban zone.

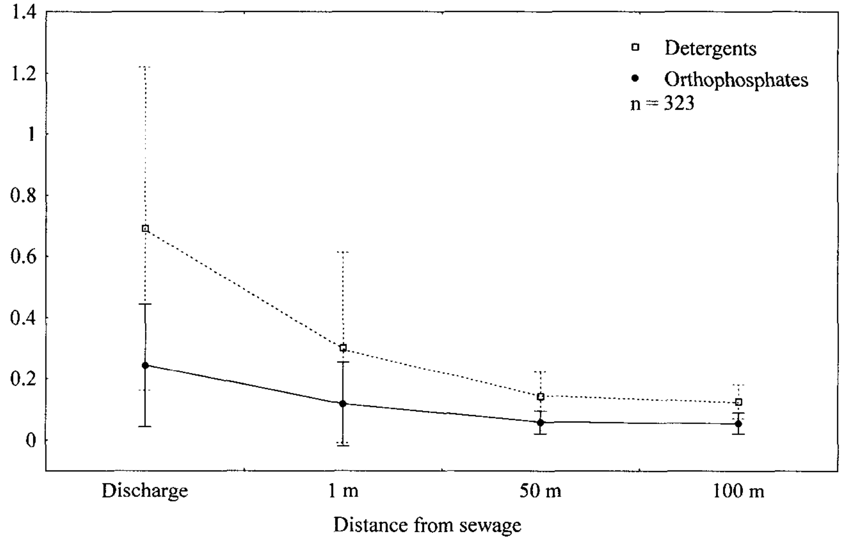

Figure 2. Detergents and orthophosphate concentrations in discharges and water column of transects. Means of value represent ±1 S D.

The phosphates diminish the hardness of water by fixing the calcium (Ca^{+2}) and magnesium (Mg^{+2}) which precipitate to sediments, so avoiding interaction with the action of detergent. The $CaCO_3$ presence in water bodies with pH above 6 allows the formation of compounds which tend to precipitate and remain in the sediments (Cheneval, 1993). Chetumal Bay presents favorable conditions for phosphorus precipitation since pH values were above 6 (Table 1) in addition to their karstic characteristics, with average concentration of $CaCO_3$ as high as 2728.5 mg l^{-1} (Chavira *et al.,* 1992). In spite of this, PO_4^{3-} was always detected, suggesting the influence of continuous and recent wastewaters discharge.

The introduction of nutrients (like nitrogen) through discharges increases the oxygen consumption by nitrification processes (Rysgaard, *et al.,* 1994). In this work, PO_4^{3-} and NO_3 + NO_2 concentrations decreased with increasing distance from discharges, with NO_3 + NO_2 values always higher with respect to PO_4^{3-} (Fig. 4). The higher values of NO_3 and NO_2 may be caused by their oxidation, favored by high concentrations of DO found in all stations (Table 1).

A negative correlation was obtained between nutrients (NO_3 + NO_2 and DO values ($r = -0.32$, $p<0.001$). Lapointe and Clark (1992) found a similar tendency in the Florida Keys, explaining that wastewater nutrient inputs increase the oxygen demand due to the bacterial mineralization of accumulated organic matter. On the other hand, the low PO_4^{3-} values probably indicate more rapid biological uptake by primary producers or adsorption in the carbonated surfaces.

Nutrients may influence phytoplanktonic biomass, phosphorus being the main limiter element for phytoplanktonic growth even when other nutrients are available (He *et* al., 1989). It was observed that chlorophyll *a* depends mainly on PO_4^{3-}, since it diminished while NO_3 + NO_2 remain elevated. The lineal correlation between chlorophyll a and PO_4^{3-} was significant ($r = 0.77$, $p<0.0001$) while the correlation between chlorophyll *a* and NO_3 + NO_2 was significant with $r = 0.42$ ($p = 0.039$), this could indicate, in relative terms, that phosphates are more limitant than nitrogen in the study area.

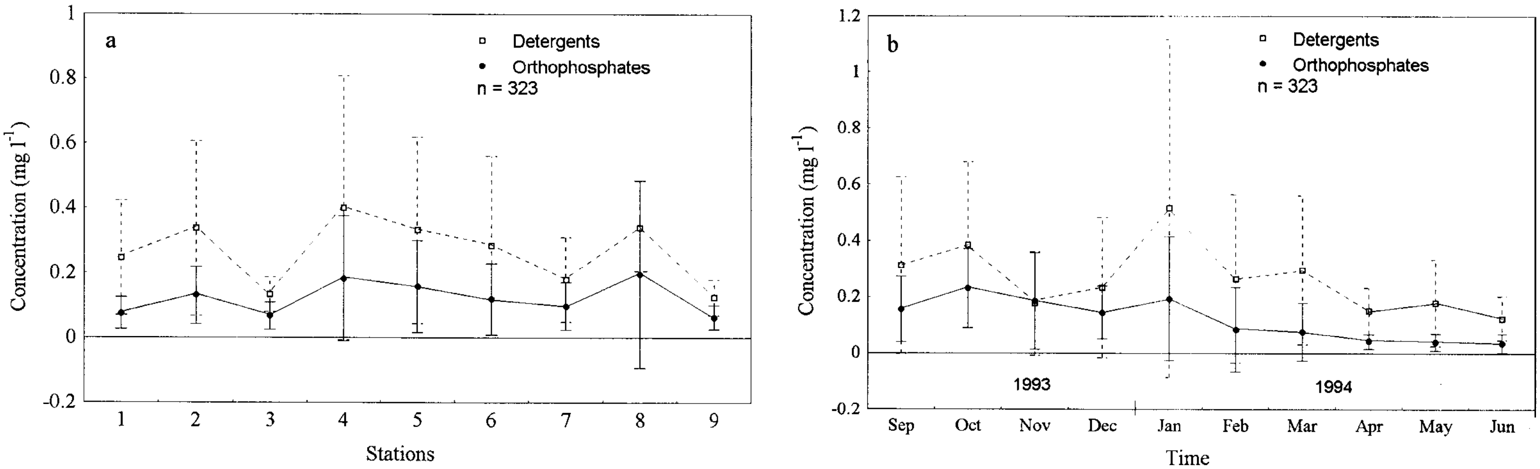

Figure 3. Detergents and PO_4^{3-} concentrations in a) stations and b) months of sampling in Chetumal Bay. Values represent ± 1 SD

Table 1. Dissolved oxygen and pH means of values in transect points in months of sampling. The values in parentheses indicated + 1 SD.

	September		October		November		December		January		March		April		May		June	
	pH	D O	pH	D O	pH	D O	pH	D O	pH	D O	pH	D O	pH	D O	pH	D O	pH	D O
Discharge	6.90	1.70	7.01	----	6.96	----	7.10	2.02	6.76	1.60	6.87	1.76	6.98	2.97	6.89	4.40	6.64	6.23
	(0.62)	(0.88)	(0.16)	----	(0.42)	----	(0.10)	(0.99)	(0.10)	(1.10)	(0.07)	(1.33)	(0.06)	(2.04)	(0.18)	(0.95)	(0.18)	(0.87)
1 m	7.06	6.07	7.10	----	7.05	----	7.35	6.51	6.86	5.74	6.89	4.79	7.01	5.52	6.98	6.13	6.90	7.27
	(0.21)	(2.16)	(0.20)	----	(0.14)	----	(0.28)	(2.16)	(0.11)	(2.62)	(0.09)	(2.38)	(0.03)	(0.77)	(0.06)	(0.52)	(0.15)	(0.23)
50 m	6.95	6.15	7.03	----	7.05	----	7.46	6.44	6.95	6.77	6.86	4.99	7.03	5.07	6.98	6.37	6.93	7.66
	(0.35)	(0.98)	(0.20)	----	(0.13)	----	(0.15)	(1.43)	(0.17)	(1.95)	(0.12)	(0.52)	(0.08)	(0.47)	(0.06)	(0.44)	(0.10)	(0.39)
100 m	6.99	5.80	7.06	----	7.05	----	7.56	5.86	7.02	5.87	6.83	4.91	7.06	5.58	6.95	5.86	6.98	7.62
	(0.34)	(0.62)	(0.25)	----	(0.11)	----	(0.17)	(1.00)	(0.14)	(1.13)	(0.07)	(0.46)	(0.07)	(0.50)	(0.07)	(0.30)	(0.14)	(0.34)

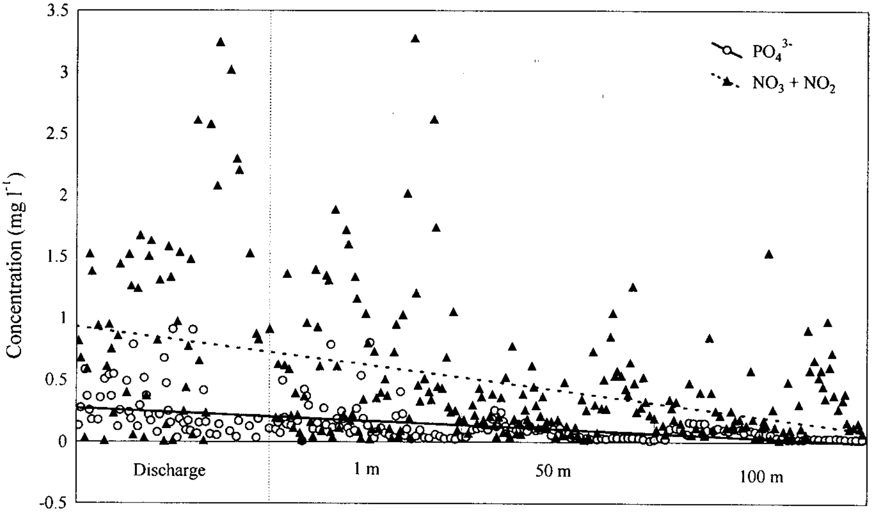

Figure 4. Tendency of orthophosphates' values and NO_3+ NO_2 values through distances.

Although detergents and nutrients decreased with increasing distance, especially at 50 and 100 m, these values surpassed those established by Water Quality Ecological Approaches for aquatic life protection: detergents = 0.1 mg l^{-1}; orthophosphates = 0.002 mg l^{-1}; nitrates = 0.04 mg l^{-1}; nitrites = 0.002 mg l^{-1} (SEDUE, 1989). Urban wastewaters into Chetumal Bay are significantly contributing to increased N and P inputs in coastal waters.

It is believed that the chlorophyll *a* values were influenced principally by the continuous contributions of orthophosphates. Given the tendency of detergents and nutrients to decrease with increasing distance, we considered that wastewater impact is limited around the urban area to approximately 200 m from the shore. Our results are consistent with previous studies carried out in several points of Chetumal Bay, which have not detected evident alteration to aquatic environment (Chavira *et al.,* 1992).

Acknowledgments. This work was part of the project 1040-N9111 financed by the Consejo Nacional de Ciencia y Tecnologia (CONACyT). We thank Roberto Flores for helping in the sampling and Julio Espinoza for his comments and suggestions on this article. We also thank to El Colegio de la Frontera Sur (formerly CIQRO).

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