BURIAL OF ORGANIC CARBON IN ESTUARINE ZONES - ESTIMATES FOR GUANABARA BAY, RIO DE JANEIRO

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Eutrophic tropical estuaries and coastal regions may play an important role in the uptake of excess CO_2 from the atmosphere. In the present paper a collection of data characterizing production and preservation of organic carbon in Guanabara Bay is used to demonstrate this hypothesis. Results show that in Guanabara Bay the estimated burial rates may reach 50g C. m^{-2}.year^{-1}, a value that is two orders of magnitude greater than those reported for ocean areas.

Keywords: carbon sink; tropical estuaries.

1. INTRODUCTION

Photosynthesis is a photobiological process by which plants, using the energy from sunlight, convert inorganic carbon and nutrients into organic compounds. Photosynthetic organisms are at the bottom of the food chain, providing highly energetic material to heterotrophic organisms that are not able to directly transform light energy into chemical energy.

In the euphotic zone, the upper layer of the oceans penetrated by sunlight, photosynthesis is carried out by algae and photosynthetic bacteria. Part of the carbon in the euphotic layer cycling between organic and mineral states due to photosynthesis, assimilation and respiration, will be transferred into deeper waters as dead organisms, fecal pellets and detrirus. In its way down the water column the organic material is consumed by respiring organisms and converted back to dissolved CO_2. In this way, biological activities in surface waters increase the concentration of carbon in the deep sea driving CO_2 from the ocean surface and, ultimately, from the atmosphere. The time required for carbon in deep ocean waters to cycle from surface to deep and back to surface is of the order of 500 to 1000 years. This time length is large compared to the time scale of the alterations in the atmospheric CO_2 balance derived from fossil fuel combustion. Therefore, through this mechanism, denominated biological pump, excesses of CO_2 in the atmosphere, after equilibration with seawater, could be driven out in a reasonably short period of time.

The process of biological pump of the oceans has been considered responsible for the sudden 50% rise in atmospheric CO_2 content after the end of the last glaciation. It is also expected to moderate the atmospheric burden of man-made CO_2 in the future[1]. The effectiveness of the biological pump in removing excess CO_2 from the atmosphere was analyzed by Wagener and Rebello[2] that concluded the process should not be significant due to the lack of extra sources of biolimiting nutrients (nitrogen and phosphorus) to the oceans.

Coastal areas, however, are preferentially enriched by man-mobilized nitrogen and phosphorus, therefore a greater stimulation of the net primary production of these zones can be expected. In this case, the carbon removal process is different from that described as the biological pump. As water depth in coastal areas is small, carbon which is fixed in the euphotic zone and is not respired in its way down the water column is fastly transferred to sediments. In the sediments, the organic material undergoes further decomposition. The fraction of organic carbon that scapes decomposition and remains buried for longer periods of time will depend on the biological activity, redox conditions and sedimentation rate. In order to provide information on the relevance of this process to the carbon balance it is important to search for the fate of marine biomass in productive coastal areas, especially where high sedimentation rates are observed.

Guanabara Bay is an appropriate ecosystem to implement first estimates on the fate of autochthonous carbon (carbon fixed *in situ*). The system is highly productive, receives direct input of man-mobilized N and P and presents sufficient sedimentation rate of inorganic material. In addition, all necessary data including net primary production, respiration rates in water and sediments, sedimentation rates and organic carbon and nitrogen in sediments are already available in the literature.

2. RESULTS AND DISCUSSION

The net primary production (NPP = difference between total carbon fixation and carbon lost by respiration) in Guanabara Bay was determined using in situ measurements of pH and dissolved O_2 over time[3], and dissolved O_2 variations in submerged bottles at 0.3, 1.2 and 2.3 m depth[4,5]. The year average calculated from these data was 0.15 L O_2. $m^{-3}.h^{-1}$ during the time of peak production, that is, between 11:00 and 15:00 h. This period accounts for 50% of the daily production, therefore, for 8h of day light the estimated NPP is 0.9 L $O_2.m^{-3}$. (day light time)$^{-1}$ or 0.48 g C fixed.m^{-3}(day light time)$^{-1}$. The depth of the euphotic zone in Guanabara Bay is presently very limited due to high loads of particulate matter. Using 2.5 m as the average depth over the whole area of the bay, the NPP given per unit area is 1.2 g C .m^{-2}.(day time light)$^{-1}$or 3 g organic matter.m^{-2}. (day light time)$^{-1}$. In order to calculate the amount of carbon fixed on a year basis a correction of 30% has to be applied to the above value accounting for night respiration. This leads to ~ 300 g C fixed . m^{-2}. year^{-1} in Guanabara Bay.

Sediment cores were taken from several stations in Guanabara Bay and at different occasions[6,7]. The 80 cm cores were divided in segments and then anlysed for their content of water, organic carbon and nitrogen, total solids and grain size. The sedimentation rates (S) were determined[8] using Pb-210; the values so far encountered varied from 0.15 cm.year^{-1} before the 50s to 1.3 cm.year^{-1} in the present. Rejecting the first 10 cm of the core, where degradation processes are still occurring[9], the concentration of organic carbon (Corg) was fairly constant at 3.18 ± 1.26 wt.% of the solids over the entire depth. Content of solids (s), that sligthly and gradually increased with depth, made up about 33 ± 15% of the total weight. The amount of carbon buried per unit of area and year (C_b) can be calculated, assuming a specific weight (d) of 1.43 $g.cm^{-3}$ for the wet sediment and using the following equation:

$$C_b = S \times s \times C_{org} \times d = 1.3\ cm.year^{-1} \times 0.33 \times 0.0318 \times 1.43\ g.cm^{-3} \times 10^4$$

$$C_b \doteq 195\ g.\ m^{-2}.\ year^{-1}$$

The C/N ratio in the core material deposited after 1950 is very close to 10. The expected C/N ratio for marine organic matter ranges between 6 and 7 while that for terrestrial biomass is 15. Using these values we can conclude that about 50% of the organic material deposited in the sediments of Guanabara Bay are derived from terrestrial sources. The percentage of marine net primary production buried in sediments of Guanabara Bay can then be estimated from the ratio of autochthonous carbon buried per unit area to carbon originally fixed via photosynthesis:

$$\%NPP_b = [0.5 \times 195\ g\ m^{-2}.year^{-1}] / 300\ g.\ m^{-2}.\ year^{-1} .\ 100 \cong 32$$

If we assume that the NPP in this area has been constant over the last 40 years or so, 32% of the NPP represents a carbon burial rate that is four times bigger than the carbon transfer into the deep sea via biological pump. In a global balance, the burial rate of organic carbon in estuarine sediments may be more important than the transfer into the deep sea via biological pump.

3. CONCLUSIONS

The anthropogenic input of nutrients to the coastal areas result in the production of additional biomass that may constitute a sink for atmospheric carbon. Tropical estuarine systems under anthropogenic influence may present extremely high rates of carbon fixation via algal production. In Guanabara Bay, for example, maximum fixation rates as large as 10 g organic matter. m^{-2}. (day light period)$^{-1}$ have been measured[4]. However, in these areas autotrophic respiration is also stimulated resulting in the recycling of a major fraction of the fixed carbon.

The net transport and storage of carbon in the sediments of a fertilized system will depend on the fixation to respiration ratio, on the sedimentation rate and on the respiratory activity in the sediments. In Guanabara Bay as in other tropical estuaries high sedimentation rates are guaranteed by extensive weathering processes and *in situ* production of particles. Based on the river fluxes and particulate load we estimated that, on the average, the input of particles to Guanabara Bay is around 2.10^5 tonnes.$year^{-1}$ while the endogenic particulate production is ~ 5.10^5 tonnes.$year^{-1}$. These high loads are responsible for the present sedimentation rate of 1.3cm $year^{-1}$ as determined[8] using Pb-210. Although respiration processes may consume almost 75% of the fixed carbon at peak productivity periods, high sedimentation rates result in the burial of 50g $C.m^{-2}.year^{-1}$ in Guanabara Bay.

The buried material appears to be very refractory to further decomposition. Experiments[9] on respiration rates in sediment cores using S-34 showed that although organic carbon and sulfate are available for bacterial utilization all over the sedimentary column examined (~ 1 m), sulfate reduction was occurring only in the first 5 to 7 cm. The lack of evidence for carbon losses due to methane formation and the rather constant carbon profile in the sediments indicate that organic carbon buried below 10 cm depth remain unchanged over periods of at least 80 to 100 years.

The above estimate of 50 g C. m^{-2}. $year^{-1}$ demonstrates that estuaries fertilized by man made N and P maybe a not negligible sink for excess CO_2, specially when compared to the burial of organic carbon in other areas of the ocean: 1.96g $C.m^{-2}.year^{-1}$ in the continental slope, 0.56 g C. $m^{-2}.year^{-1}$ in shelf areas and 0.015 g C $m^{-2}.year^{-1}$ in the ocean floor[10].

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