Proceedings of 8 ICSHMO, Foz do Iguaçu, Brazil, April 24-28, 2006, INPE, p. 663-667.

GAS RELEASE BELOW BALBINA DAM.

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Introduction

As scientists and governments become increasingly concerned about the growing evidence of global warming, reducing the emissions of greenhouse gases is gradually emerging as a common goal. Hydroelectric power has been promoted as an environmentally clean energy source. However, this view has begun to change. Some hydroelectric reservoirs have been found to release more greenhouse gases (GHGs) per megawatt than analogous fossil fuel plants (1, 2). While most research has focused on gas emissions from reservoirs, it has been argued that emissions downstream from hydroelectric dams, resulting from the rapid depressurization of reservoir bottom waters, could be considerably higher (1, 2, 3). The water intake for most hydroelectric dams is located near the bottom of the reservoir to guarantee sufficient head pressure to operate the turbines. As gas-rich water passes through the turbines and is exposed to the atmosphere, the hydrostatic pressure drops immediately, and a large portion of the gas is released as bubbles. This occurs quickly, offering little opportunity for oxidizing bacteria to consume the methane. Here we present the results of detailed measurements of GHG emissions downstream of Balbina Dam, one of the largest hydroelectric power plants in the Brazilian Amazon.

Materials and Methods

To provide an accurate estimate of the total flux downstream from the dam and improve estimates of the total release of GHGs from the entire system, we made regular estimates of the two principle downstream emission components: 1) gas ebullition as the reservoir waters passed through the turbines and 2) diffusive gas losses in the river channel below the dam. The total initial downstream gas flux for both methane and CO_2 was estimated from the product of turbine discharge and the gas concentration at the turbine intake (TIF). Immediate gas ebullition upon passage through the turbines was estimated from the product of water discharge through the turbines and the difference in dissolved gas concentrations at the intake and outlet of the turbines. Diffusive gas emission in the downstream channel was measured at approximately 4000 m intervals along a 70 km reach immediately below the dam, using a drifting static chamber method. Methane and CO_2 concentrations were determined sequentially using a dual column gas chromatograph (4).

Results

Positive linear relationships were encountered between turbine discharge and both total initial downstream gas flux (CH_4 TIF = -275.2 + 0.97 [discharge], n= 8, R^2= 0.76, $p< 0.05$; and CO_2 TIF = -147.1 + 0.85 [discharge], n= 8, R^2= 0.92, $p< 0.05$) (Fig. 1A) and immediate ebullitive gas emissions (CH_4 emission = -197.4 + 0.63 [discharge], n= 8, R^2= 0.83, $p< 0.05$; and CO_2 emission = -145.2 + 0.56 [discharge], n= 8, R^2= 0.87, $p< 0.05$) (Fig. 1B). These relationships were used together with daily discharge values to estimate the total annual TIF and ebullitive gas fluxes for Balbina dam in 2004 (Table 1). The results indicated that 53% of the CH_4 and 48% of the CO_2 which passed through the turbines, on average, was immediately lost to the atmosphere through ebullition. The ebullitive release of methane was lower than the average loss of 87%, estimated from three measurements reported for Petit Saut dam in French Gyana (3).

After the initial ebullitive loss, the residual concentrations of carbon dioxide and methane in the Uatumã River fell gradually until approximately 30 km below the dam (CO_2: n= 38, $p< 0.05$, $R^2= 0.41$; CH_4: n= 38, $p< 0.05$, $R^2= 0.56$) (Fig. 2). Applying these average loss rates to the daily residual fluxes estimated during 2004, resulted in total annual carbon losses of 4.5 and 25.8 Gg for diffusive emission and oxidation, respectively. For the present analysis we assumed that diffusive emissions of CO_2 included 100% of the residual downstream gas flux plus the CO_2 equivalent of downstream methane oxidation, resulting in a total annual diffusive flux of 71.3 Gg (Table 1).

Discussion

When both ebullitive and diffusive emissions are considered, the estimated annual release of methane and CO_2 downstream of Balbina dam were 39 and 114 Gg, as carbon, respectively. This methane emission represents 60% of the total initial downstream flux. The underwater release of turbine effluents contributed to reduction of emissions in this case by increasing the proportion of the initial flux consumed by oxidizing bacteria. Despite this reduction, the final flux is still regionally significant, contributing the equivalent to 3% of the emissions generated by the entire central Amazon floodplain (5). This type of emission must clearly be considered when evaluating the environmental costs of this and other hydroelectric reservoirs. The 100 year integrated global warming potential of methane is 21 times greater than that for carbon dioxide (6). This effect is important to consider when evaluating the potential contribution of CO_2 and methane emissions to climate change. The CO_2 released to the atmosphere following decomposition is balanced by the CO_2 which was fixed during the production of the original organic matter, resulting in a net warming effect close to zero. For methane emissions, the carbon balance is similar, but the global warming effect of the methane released following decomposition is 21 times greater than that of the atmospheric CO_2 originally fixed by plants. The downstream methane flux from this single reservoir has the atmospheric warming potential of 6% of the fossil fuels consumed in the Brazilian metropolis of São Paulo (7).

References and Notes

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WWF, NASA, CNPq, INPA, UCSB, IBAMA and Manaus Energia for financial and logistical support.

Table 1. Estimated annual fluxes of CO_2 and CH_4 downstream of Balbina reservoir for 2004 (all values in Gigagrams of carbon per year).

FLUX COMPONENT	CH_4	CO_2
Total initial downstream gas flux (TIF)	64.7	88.2
Ebullitive emission	34.4	42.7
Diffusive emission	4.5	71.3
Oxidation loss	25.8	-
TOTAL EMISSION	38.9	114.0
CO_2 carbon equivalent	297.1*	114.0

*** converted to carbon dioxide equivalent carbon using a global warming factor of 21 ($kgCO_2/kgCH_4$), calculated over a 100 year time horizon (11).**

Figure 1. Relationships between turbine discharge and both total initial downstream gas flux (A) and immediate ebullitive gas emissions (B) for methane (○) and CO_2 (●).

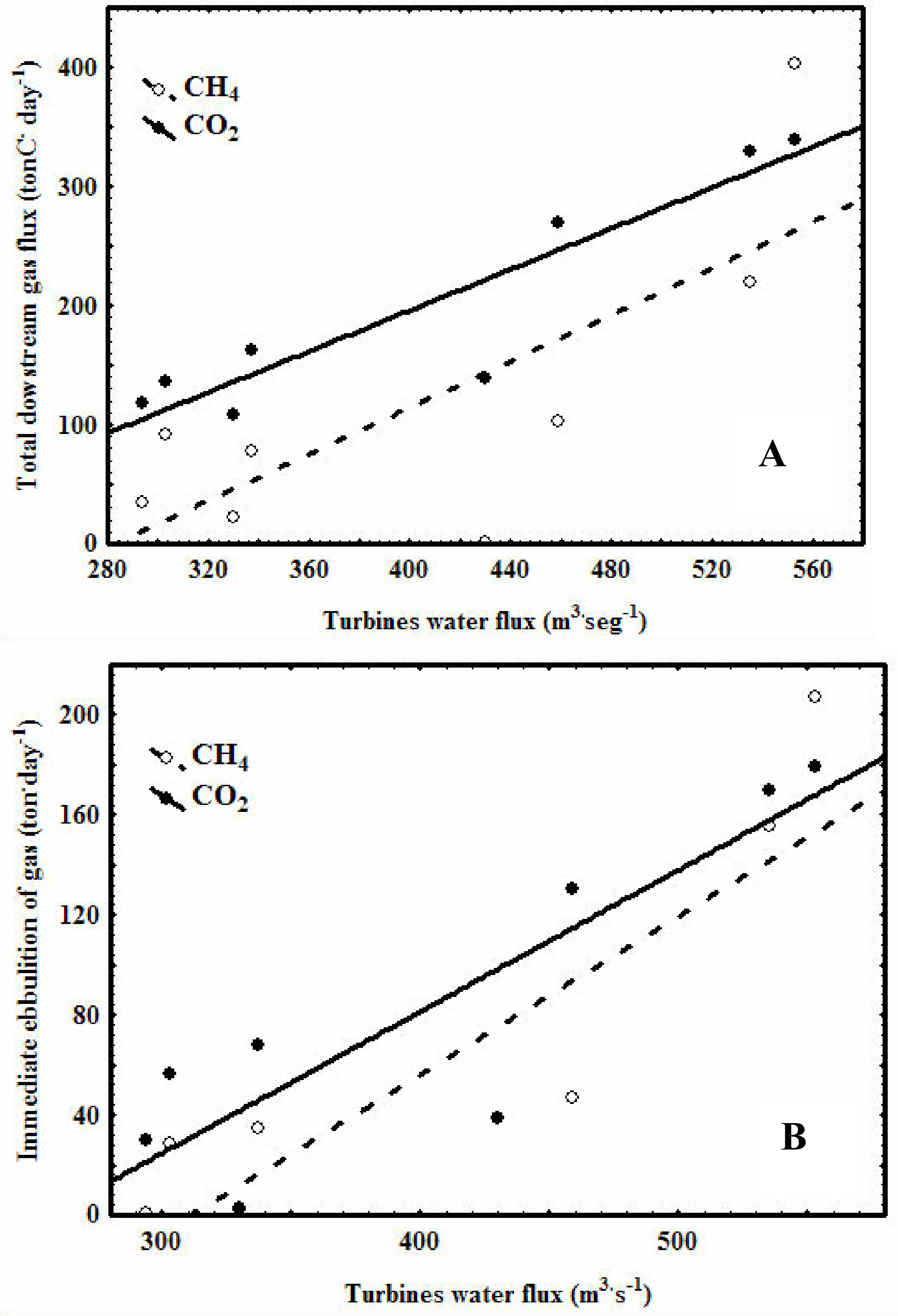
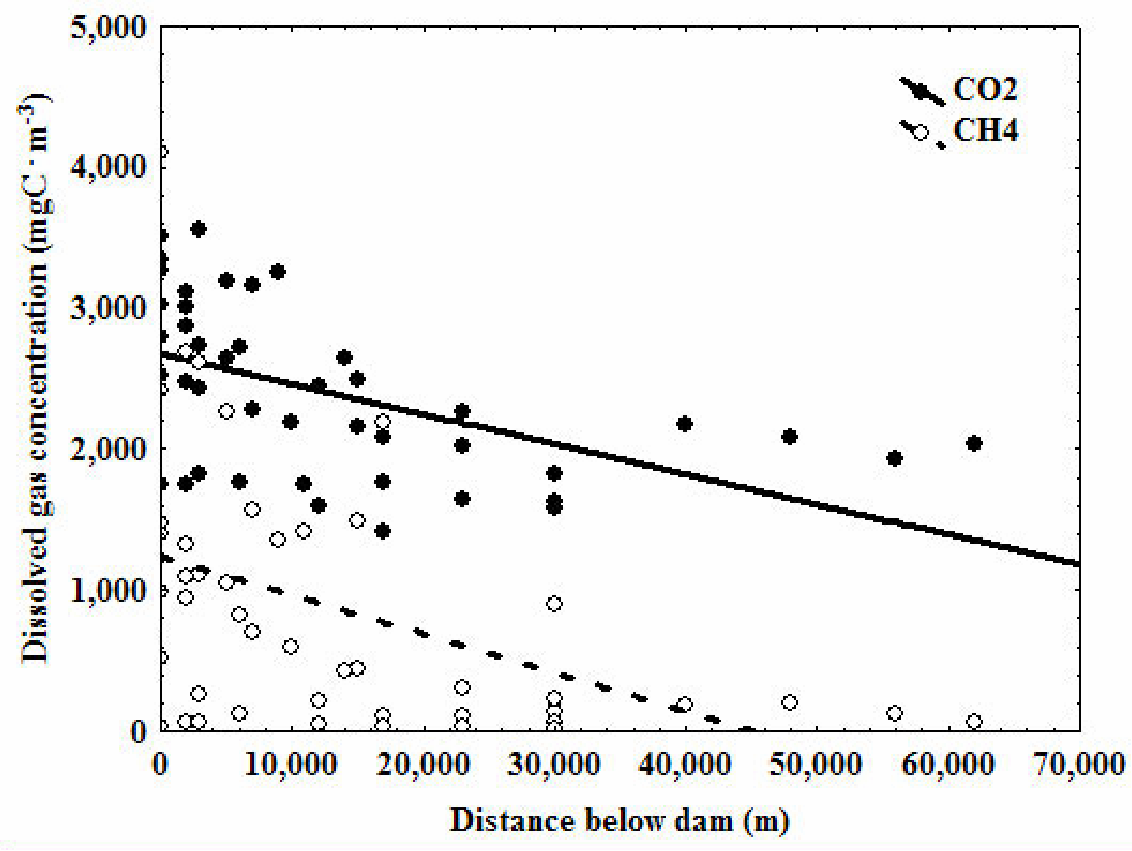


Figure 2. Variation in surface concentrations of methane (○) and CO_2 (●) downstream of Balbina dam.


CO2
CH4
Dissolved gas concentration (mgC · m-3)
5,000
4,000
3,000
2,000
1,000
0
0
10,000
20,000
30,000
40,000
50,000
60,000
70,000
Distance below dam (m)