# Exploring Carbon Credit Potential of Constructed Wetlands for Wastewater Treatment in Small Brazilian Communities: revenues estimations for OPEX financing

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Highlights:

- Operating and maintaining a wastewater treatment plant are crucial factors for small communities with decentralized sanitation systems;
- Carbon credit generated by using Constructed Wetlands could be used for financing Operational Expenditures of a wastewater treatment plant;
- Revenue generation through carbon credits in the sanitation context offers a novel approach to valuing these services.

Keywords: Constructed Wetlands; Greenhouse Gas; Carbon Credit; OPEX

## INTRODUCTION

The sanitation scenario in Brazil faces significant challenges, particularly regarding wastewater treatment. According to the 2020 report by the National Water Agency (ANA) titled "Atlas do Esgoto," only 1,997 out of 5,570 Brazilian municipalities are served by Wastewater Treatment Plants (WWTPs), totaling 3,698 operational units (ANA, 2020). The state of Minas Gerais, in Brazil, is a proper representation of this Brazilian scenario, with only 266 municipalities out of the total 853 declaring having an active WWTP (ANA, 2020). A significant portion of the municipalities without treatment services are small communities, with under 5,000 inhabitants. This situation highlights the significant disparities in access to essential sanitation services and underscores the urgent need for targeted interventions to enhance wastewater treatment capabilities in underserved areas.

The new framework for basic sanitation stipulates that 90% of the Brazilian population should have access to sanitation services by 2033 (Brazil, 2020). Given the context of ecological transition, investments in the sanitation sector in Brazil should prioritize installation of low-carbon technologies, with the goal of achieving universal and sustainable service provision. However, difficulties extend beyond installing a WWTP, as operating and maintaining the plants are also crucial factors. In this context, Constructed Wetlands (CWs) present themselves as an interesting solution, with easy and inexpensive operational costs that can be further reduced by their potential for carbon credit generation. This work aims to estimate the Greenhouse Gas (GHG) emissions by CWs, the revenue generated by carbon credits and, consequently, the reduction in operational expenses (OPEX) through this gain.

## METHODOLOGY

In this research, Methane ($CH_4$) and Carbon Dioxide ($CO_2$) emissions were evaluated. The emissions were determined through both theoretical modeling and experimental methodologies.

Experiments to measure GHGs emissions were conducted in May 2024, at the Technological Park of Belo Horizonte (BHTec) in Minas Gerais, Brazil (coordinates 19°53'06" S and 43°58'29" W). The system evaluated is a modular Constructed Wetland with a vertical subsurface flow system (VSSF) with a saturated bottom, designed to treat raw domestic sewage from BHTec building, with an inflow rate of 2.22 m³/d. The modular CW is composed by two 2.30 x 2.25 m beds, a total filter height of 0.80 m (0.40 m fine clay; 0.40 m coarse clay + Bio-bob®) and 0.40m saturated bottom, functioning in a batch-mode alimentation, with an intermittent aeration system and a 3,5/3,5 days feeding-resting turns.

For GHG sampling, two static cylindrical closed chambers (PVC – 150 x100 mm) were distributed over the beds, and samples collected at 0, 15, 30, 45, and 60-minutes intervals. Subsequently, they were analyzed using Gas Chromatography coupled with TCD and FID detectors (Shimadzu GC) to determine $CH_4$ concentrations. The emission flux is calculated using the following formula (EMBRAPA, 2014):

$$\phi = \frac{\partial C}{\partial t} \times \frac{V}{A} \times \frac{m}{V_m}$$

Φ = Emission flux (µg.m-2.h)
∂C/∂t = Rate of gas concentration change within the chamber per unit time (ppm/h)
V/A = Chamber's volume (m³) and area (m²)
m/Vm = Molecular weight (g) /volume (m³)

For $CO_2$ emission factor estimation, a correction factor of 4% was included, in order to only compute non-biogenic carbon dioxide generated in wastewater treatment (IPCC, 2019). Emissions factors calculated considering treatment system area and flow rate.

The theoretical calculation followed the methodology employed by Boratto et al. (2021), which utilized data from IPCC (IPCC, 2014) to calculate the annual $CH_4$ emission factor for various wastewater treatment technologies, including anaerobic reactor arrangements Upflow Anaerobic Sludge Blanket combined with Biological Trickling Filter (UASB + BTF), Activated Sludge (AS), and CWs.

The theoretical carbon emissions data were used to evaluate GHGs emission reduction, by determining the carbon emissions mitigation potential attributed to the utilization of CWs in comparison to other technological approaches. Finally, the annual revenue from carbon credits was determined, and subsequently, the corresponding value was subtracted from the OPEX allocated to CWs when employed as the treatment technology for small communities from Minas Gerais (up to 5,000 inhabitants), to evaluate the percentage of operational expenditures financed by carbon allowances.

## RESULTS AND CONCLUSIONS

Experimental results are shown in Table 1. The emission factors per capita calculated for $CH_4$ are higher than those reported by the IPCC (2014), likely due to the increased organic loads in the wastewater treated by the modular system, which can reach Chemical Oxygen Demand (COD) concentration levels of up to 1400 mg/L.

| Greenhouse gas | Emission flux ($g/m^2.d$) | Gas emission ($kgCO_2$ or $CH_4$/year) | EF ($kgCO_2$ or $CH_4$/kgDBOrem) | $EF_{per\ capita}$ ($kgCO_2$ or $CH_4$/PE.year) |
|---|---|---|---|---|
| Methane ($CH_4$) | 2,27 | 10,50 | 0,021 | 0,700 |
| Carbon dioxide ($CO_2$)* | 13,20 | 2,44 | 0,005 | 0,061 |

*4% of total $CO_2$ emission (IPCC, 2019)

***Table 1.*** Methane and carbon dioxide emission flux and emission factors

Theoretical results for $CH_4$ emissions and carbon emissions reductions are disposed in table 2.

| | $\Phi_{CH4}$ (kg $CH_4$/PE.year) | $\varphi_C$ (ton C/PE.year) | Emission reduction (%) | Reduction (tonC/PE.year) |
|---|---|---|---|---|
| CW | 0,13 | 0,004 | - | - |
| UASB + BTF | 8,76 | 0,245 | 99% | 0,242 |
| AS | 0,35 | 0,010 | 63% | 0,006 |

***Table 2.*** Methane emission flux ($\Phi_{CH4}$), carbon emission equivalent ($\varphi_C$) and annual reduction of $CH_4$ emission by using CWs (UASB: Up flow Anaerobic Sludge Blanket; BTF: Biological Trickling Filter; AS: Activated Sludge)

Thereafter, the higher emission reduction (comparison with UASB+BTF) was chosen to continue the estimations. Furthermore, since UASB is the most widely used wastewater treatment technology in Brazil and in Minas Gerais, emission reductions are accurately calculated by comparing them to those of traditional solutions. The average population for each hydrographic basin of Minas Gerais was determined and, by applying the previous calculations for carbon emission reduction to this data, carbon credits were calculated. The OPEX costs includes energy, workforce, sludge, chemicals, operational, periodic maintenance, maintenance (after 10 years for sludge removal) for a CW (filter area 0.8 $m^2$/PE). Since Brazil still does not have a regulated carbon trade market, an average value of U$10.00 for carbon crediting was used as voluntary carbon credit value (CGEE, 2010), amount verified by Brazilian carbon credit certifiers after consulting. The dollar conversion value adopted was based on Bloomberg X-rate, on August 20th, with 1 USD = 5.47 BRL (Bloomberg X-Rate, 2024). Table 3 shows the results for carbon credit and OPEX reduction calculations.

| Hydrographic Basin | Average population* | Reduction (tonC/year) | Carbon credit revenue (USD/year) | Carbon credit revenue (BRL/year) | OPEX (BRL/year) | Carbon credit/OPEX (%) |
|---|---|---|---|---|---|---|
| Eastern Basins | 3889 | 939,73 | $9.397,35 | R$ 51.468,32 | R$ 84.373,09 | 61,0% |
| Doce River | 2960 | 715,25 | $7.152,52 | R$ 39.173,63 | R$ 64.520,74 | 60,7% |
| Grande River | 2976 | 719,12 | $7.191,18 | R$ 39.385,38 | R$ 64.862,65 | 60,7% |
| Jequitinhonha River | 3273 | 790,88 | $7.908,85 | R$ 43.315,97 | R$ 71.209,42 | 60,8% |
| Mucuri River | 3224 | 779,04 | $7.790,45 | R$ 42.667,49 | R$ 70.162,31 | 60,8% |
| Pardo River | 3878 | 937,08 | $9.370,77 | R$ 51.322,74 | R$ 84.138,03 | 61,0% |

| | | | | | | |
|---|---|---|---|---|---|---|
| Piracicaba, Capivari e Jundiaí Rivers | 2681 | 647,83 | $6.478,34 | R$ 35.481,25 | R$ 58.558,62 | 60,6% |
| Paranaíba River | 3014 | 728,30 | $7.283,00 | R$ 39.888,28 | R$ 65.674,69 | 60,7% |
| Paraíba do Sul River | 2626 | 634,54 | $6.345,44 | R$ 34.753,36 | R$ 57.383,29 | 60,6% |
| São Francisco River | 3117 | 753,19 | $7.531,89 | R$ 41.251,42 | R$ 67.875,76 | 60,8% |
| São Mateus River | 3263 | 788,47 | $7.884,68 | R$ 43.183,63 | R$ 70.995,72 | 60,8% |

*Per municipality, for municipalities with under 5,000 people

***Table 3****. Carbon credit revenue (BRL/year) and OPEX reductions for average population municipality in each hydrographic basin in Minas Gerais state.*

As demonstrated by the results, considering the current scenario of the carbon credit market in Brazil, CWs can contribute up to 61% of the annual OPEX reduction for small municipalities. Moreover, these results might be even more significant with the approval of regulations for the carbon credit market, as evidenced by international cases, where allowances typically hold higher value (CGEE, 2010). For instance, in Europe, one carbon credit has an average value of €60,00, equivalent to approximately R$330,00 (EU-ETS, 2024).

Wastewater treatment has traditionally had a low investment incentive due to its high fixed costs in highly specific capital (Turolla, 2002). Consequently, revenue generation through carbon credits in the sanitation context can help boost advancements in the sector, as it offers a novel approach to valuing these services.

## REFERENCES

ANA – Brazilian National Water and Sanitation Agency (Agência Nacional de Águas e Saneamento Básico) 2020. Atlas Esgotos: Despoluição de Bacias Hidrográficas. April, 2020, BRAZIL.

Bloomberg X-rate 2024. Dolar conversion value – USD to BRL exchange value on 20th August 2024. Retrieved from https://www.bloomberg.com/quote/USDBRL:CUR. Access on 20th August 2024.

Boratto, D. C.; Barreto, A. B.; Sezerino, P. H.; Souza, C. L. 2021. Wetlands construídos empregados no tratamento de esgoto sob o contexto do saneamento de baixo carbono. Revista Ibero Americana de Ciências Ambientais, v.12, n.7, p.390-405.

Brazil 2020. Federal Law N° 14.026, from July 15th 2020. Atualiza o marco legal do saneamento básico e altera a Lei nº 9.984, de 17 de julho de 2000. July, 2020, Brasília, BRAZIL.

CCGE – Brazilian Center for Management and Strategic Studies (Centro de Gestão e Estudos Estratégicos) 2010. Manual de capacitação sobre Mudança climática e projetos de mecanismo de desenvolvimento limpo (MDL). Brasília, BRAZIL.

EMBRAPA – Brazilian National Entreprise for Agropecuary - Forest sector 2014. Protocolo para medição de fluxos de gases de efeito estufa do solo. 2014, Colombo, Paraná, BRAZIL.

EU-ETS – European Emissions Trading System 2024. Allowances prices for carbon emission. Retrieved from: https://tradingeconomics.com/commodity/carbon. May 2024.

IPCC – International Panel on Climate Change 2014. Constructed Wetlands for Wastewater Treatment. In: 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands. SWITZERLAND.

IPCC – International Panel on Climate Change 2019. Wastewater Treatment and Discharge. In: 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 5: Waste. SWITZERLAND.

Turolla, F. A. 2002. Política de saneamento básico: avanços recentes e opções futuras de políticas públicas. IPEA, Brasília, BRAZIL.