Greenhouse gas emission in decentralized wastewater treatment plants for isolated communities

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Highlights:

- Assessment of greenhouse gas emission from treatment plant in decentralized system by design for establishing criteria help in the selection of technology

Keywords: Greenhouse gas emissions; Small sewage treatment plant; Isolated communities

INTRODUCTION

Climate change has been on the world's agenda for some time. Every day we are watching the consequences of the devastating effects of the Planet's response to human interference in the global climate balance. The most recent climate tragedy in Brazil, the floods in the state of Rio Grande do Sul in September 2023 that impacted 100 cities, raising the level of Taquari, Jacuí and Caí rivers by up to 15 meters. It is estimated that more than 350,000 people were affected, with thousands of displaced and significant material losses. The strong waters also resulted in dozens of deaths and missing, as well as damage to infrastructure and plantations in the region.

The treatment of effluents is essential for the preservation of water bodies, and depending on the technology, it can generate reusable water for non-potable purposes. Although this premise, as well as all anthropogenic activity, the effluent treatment process can produce greenhouse gases such as nitrous oxide (N_2O), carbon dioxide (CO_2), and methane (CH_4) (Kampschreur et al., 2009).

According to Kampschreur et al. (2009), CO_2 is directly linked to energy consumption in the effluent treatment plant (WWTP). In the case of methane, its emission occurs constantly in the sludge treatment and handling system (Kampschreur et al., 2009).

In the case of N_2O, release occurs mainly during biological nitrogen removal. Depending on the system configuration, nitrogen removal levels from wastewater can be high, promoting nitrification and denitrification (Law et al., 2011).

The sanitation sector has been seeking to make its contribution to reducing the impacts of its operation on climate change. Through surveys of their emissions generated and ways to seek to reduce them. This work seeks to analyze the emissions based on the GH PROTOCOL program of 6 small sewage treatment plants that treat locally the sewage of isolated communities and seeks to formalize criteria for choosing the best treatment concepts.

METHODOLOGY

To achieve the objectives of the study, the selection of Small Treatment Plant SWWTP or DWTP located in a city in the Brazilian southeast region was initiated. In general, we sought to select stations that receive effluents from housing complexes, with this, Table 01 has the six stations found, which were called A, B, C, D, E and F, as well as population served, flow, treatment system, start of operation, active age, power, and area used.

DWTP	Start-up Year	Technology	Current Population (inhabitants)	Flow (L/s)	Installed Power (kW)	Deployment Area (m²)
A	2014	CEPT* + MBBR** + Fixed Media + Secondary Settling	6,038	7	55	1,718
B	2016	Mobile: CEPT* + Fixed Media + Secondary Settling	1,913	3	15	450
C	2017	Activated Sludge: Prolonged Aeration	1,628	3	51	2,308
D	2012	Upflow Anaerobic Reactor + SABF*** + Secondary Settling + Contact Tank	3,500	5	10	670
E	2007	Septic Tank + Anaerobic Filter + Contact Tank	2,252	5.58	2	1,960
F	2007	Septic Tank + Anaerobic Filter	3,195	7.02	2	6,706

*CEPT: Chemically Enhanced Primary Treatment
**MBBR: Moving Bed Biofilm
***SABF: Submerged Biological Filter

Table 1. Decentralized Small Wastewater Treatment Plant SWWTP or DWTP Characterization.

For the quantification of the emitted gases will be adopted the methodology of calculation of the Brazilian GHG Protocol Program (De Azevedo et al., 2018) and the monitoring data of the management company of the systems. In addition, with the quantification finalized, the results will be compared with other studies in the area.

RESULTS AND CONCLUSIONS

According to methodology, the results are in Table 2.

DWTP	Conception Design	Technology	Volume Treated [m³/year]	Emission [tonCO₂/year][1]	Emission [tonCO₂/year][2]	Emission per Capita [kg/m³]	Sludge for Landfill [ton/year]
A	Aerobic	CEPT* + MBBR** + Fixed Media + Secondary Settling	218.974,00	249.219,00	261.151,00	1,14	518,4
B	Aerobic	Mobile: CEPT* + Fixed Media + Secondary Settling	70.426,37	75,18	79,46	1,07	71,16
C	Aerobic	Activated Sludge: Prolonged Aeration	65.655,00	53,37	55,08	0,81	43,8
D	Mixed Aerobic and Anaerobic	Upflow Anaerobic Reactor + SABF*** + Secondary Settling + Contact Tank	79.555,00	459.766,00	464.644,00	5,78	21,84
E	Anaerobic	Septic Tank + Anaerobic Filter + Contact Tank	126.034,00	1.218,78	1.222,592	9,67	10,92
F	Anaerobic	Septic Tank + Anaerobic Filter	107.468,00	1.007,85	1.010,57	9,38	10,92

[1] Total emissions without considering by truck.
[2] Total emissions including sludge transport truck.
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Table 2. Comparison of emissions by treatment design.

Comparing the results obtained, Plant D shows the highest CO_2 emissions in both scenarios (without and with sludge transportation emissions by truck), followed by Plants A, E, F, B, and C. Studies on centralized wastewater treatment plants reported CO_2 emissions of 1,317,375 and 71,696 tons per year for UASB and Activated Sludge technologies, respectively (Singh et al., 2017), as seen in Plants D and C of this study. Singh et al. (2017) examined plants with capacities of 2,326 and 979 million liters per day for UASB and Activated Sludge, respectively, which are significantly larger than the decentralized wastewater plants analyzed here.
Specifically, regarding the technology used in Plant D, which had the highest emissions level, J.-J. Lu et al. (2022) investigated the use of vegetation to reduce greenhouse gas emissions in decentralized wastewater treatment plants. Their results showed that annual GHG emission fluxes decreased by 19.79% compared to the approach without vegetation in aerobic technology (J.-J. Lu et al., 2022). Therefore, vegetation cultivation could be a viable option for reducing emissions in the aerobic technology plants analyzed in this study.
Finally, according to Zhuang et al. (2020), can result in relatively high GHG emissions, despite its low energy consumption, if used as the sole treatment due to emissions from the receiving body. Therefore, the configuration of Plant B is shown to be a good approach in terms of reducing GHG emissions.

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