

Carbon Gas Emissions (CO₂ and CH₄) in Coastal Community Settlement Area in The Mawasangka District - Central Buton, Indonesia

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Abstract: Coastal communities often establish settlements above the sea, where domestic waste is discharged into residential areas and subsequently decomposes, releasing carbon gases. This research aimed to analyze carbon gas emissions from such settlements. Gas sampling was conducted using a chamber in both a densely populated area (PP) and a sparsely populated area (JP), with concentrations measured by gas chromatography (GC-MS). Differences between the two regions were assessed using one-way ANOVA. Results showed that average CO₂ concentrations differed significantly ($p = 0.000067 < 0.05$), whereas CH₄ concentrations did not ($p = 0.1721 > 0.05$). CO₂ emissions in PP (13.36 mg·m⁻²·h⁻¹) were significantly higher than in JP (5.42 mg·m⁻²·h⁻¹; $p = 0.00071 < 0.05$). Similarly, CH₄ emissions were greater in PP (0.036 mg·m⁻²·h⁻¹) than in JP (0.014 mg·m⁻²·h⁻¹; $p = 0.03 < 0.05$). The global warming potential (GWP) of PP reached 14.403 mg CO₂-eq·m⁻²·h⁻¹, exceeding that of JP (5.822 mg CO₂-eq·m⁻²·h⁻¹). These findings indicate that coastal settlements in Mawasangka Subdistrict contribute substantially to atmospheric greenhouse gas emissions, particularly CO₂, driven by population density and waste accumulation. Effective management of greenhouse gas emissions and GWP is therefore necessary to prevent further increases.

Keywords: Carbon gas emission, settlement area, methane, global warming

1. Introduction

The climate change that results from global warming impacts vital sectors, including fisheries (Badjeck et al., 2010; Shawket et al., 2019). High intensity rainfall and the shifted timing of rainy season and dry season as well the sea level rise pose risks to coastal areas and trigger climate-related disasters. As reported by Brander (2010) and Wang et al. (2016), climate change increases several parameters that affect the ecological conditions, including water temperature, salinity, oxygen, wind speed, waves, and sea level. Consequently, fishery production declines, leading to lower human livelihoods and welfare (Jones, 2013; Asch et al., 2018).

Several contributors of climate change include the high amount of greenhouse gases in the atmosphere, primarily carbon emissions such as CO₂ and CH₄ (IPCC, 2001). Carbon emissions are emitted from human activities and natural processes, such as the degradation of organic waste in coastal and marine ecosystems. The average carbon emissions varies from 0.0003 – 347 mg·m⁻²·h⁻¹ (Lovelock et al., 2011; Dutta et al., 2013). Research on emissions

and the potential for global warming has been carried out in various ecosystems, such as peat swamps, mangroves, rice fields, and tropical rainforests.

The coastal community of Mawasangka District - Central Buton Regency built settlements above the sea in the coastal area where they dispose domestic organic and inorganic waste to the water. The waste is retained and deposited on the bottom of the water or sediment and undergoes decomposition, which triggers the release of carbon gas. The amount of emissions and the global warming threat from domestic waste among coastal communities should be further investigated.

The present research analyzed the emissions and global warming potentials from anthropogenic waste from the community in coastal areas. The results of this research are expected to become recommendations for policymakers to manage low-emission coastal community settlements in the forms of effective waste management.

2. Materials and Methods

Description Of Studi Sites

This research was conducted from July to August 2022 in a residential area located at the coastal area of Mawasangka Buton Tengah District. Two stations were determined as the research sites; station I (PP) for densely populated areas and station II (JP) for sparsely populated areas (Figure 1).

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Received: April, 2023

Accepted: September, 2024

Published: September, 2025

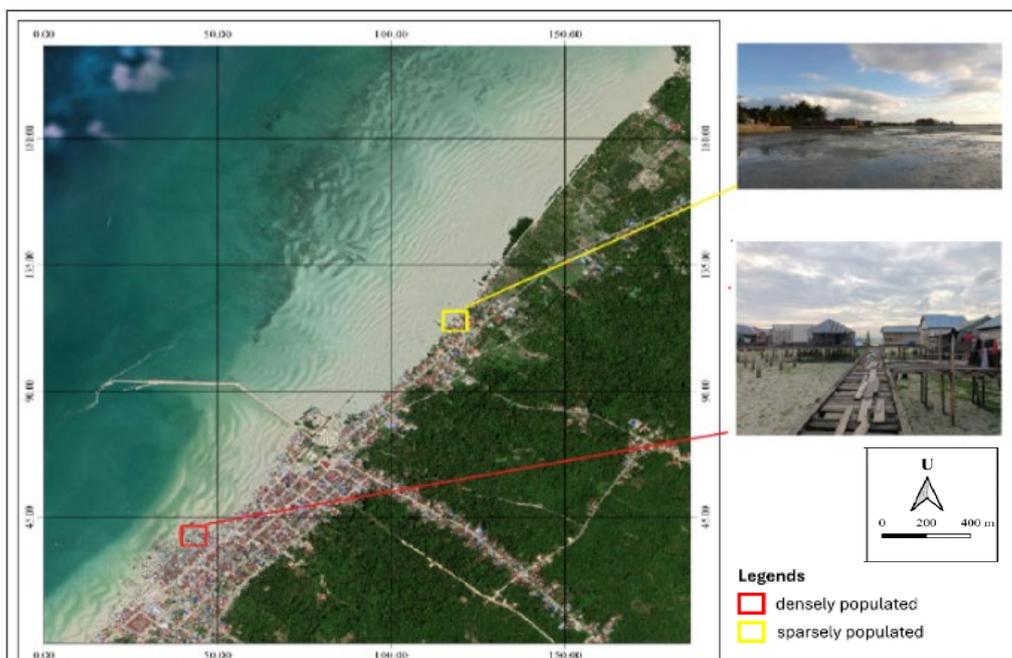


Figure 1. Map of research sites in densely populated and sparsely populated areas

Materials

Several tools were employed during the research, including thermometers, hand-refractometers, cylinder hoods, syringes, vials, syringes, GPS, and statistical analysis software such as SPSS or other relevant (Table 1). The containment used is 19 – 20 L gallon with a base diameter of 28 cm, that was cut at the bottom for the sediment trapping area, leaving a final volume of 17 L (Figure 2).

Table 1. Materials for data sampling

No	Materials	Functions
1	Thermometer	Measures the temperature in the enclosure
2	Hand-refractometer	Measures the salinity of the substrate water
3	Chamber (volume 17 L)	Carbon gas trap (Figure 2)
4	Syringes	Take gas in the chamber
5	Injection (100 ml)	Take gas through a syringe
6	Vial bottles (10 ml)	Store carbon gas
7	GC-MS	Measures the concentration of carbon gas
8	GPS	Determines the coordinat points



Figure 2. Design of chamber to take carbon gases

Data Samplings

Water quality parameters (temperature and salinity) were measured in situ at intervals of 10 minutes each during the gas sampling period to determine their effects on carbon emission values.

Gas sampling was done by placing a lid on the substrate under the houses in the PP and JP areas. Each area consisted of 5 points for laying the containment with a distance of 20 meters between points and 10-minute time interval for gas collection. At each point, the hood was placed for 120 seconds, and gas was sampled five times at 30-second intervals (t = 0, 30, 60, 90, and 120 s) following the method of Lin et al. (2020). Samples were stored in 10-ml vials (Rahman et al., 2018; Rahman et al., 2020a) and subsequently analyzed in the laboratory for carbon gas concentrations.

Data Analysis

Concentration of Carbon Gases

The concentration of carbon gas (CO₂ and CH₄) was measured using the gas chromatography method (GC-MS). A variance test was carried out to see whether there was a difference in the average concentration of carbon gas between the PP and JP areas in the form of ANOVA-Single Factor test on SPSS software version 23.

Carbon Gas Emissions

Carbon emission values were calculated using the equation proposed by Rahman et al. (2020a). Differences in mean carbon emissions were tested using Single-Factor ANOVA with SPSS version 23.

$$F = \left| \frac{S * V * t * mW}{(RT * A)} \right|$$

Where : F: Flux of carbon gas (µg.m⁻².h⁻¹), S: regression slope of the concentration of carbon gas measured every 30 seconds (ppm/s), V: volume of the containment (L), A = area covered by the containment (m²), R: ideal gas constant (0.082 L.atm.K.mol⁻¹), T: temperature in the chamber or air temperature (K), t: time transformation constant = (1 hour/gas sampling time interval = 3600 seconds /30 sec = 120), and mW: relative atomic mass of C (CO₂: 44g.mole⁻¹, and CH₄: 16 g.mole⁻¹).

Global Warming Potential

The Global Warming Potential (GWP) of greenhouse gases corresponds to the radiative forcing by CO₂ concentrations in the atmosphere (IPCC, 2001). The GWP value for carbon gas was calculated using the formula proposed by the Intergovernmental Panel on Climate Change (IPCC, 2001) as follows.

$$F_e = F_m \times GWP$$

Where: Fe is the CO₂-equivalent flux value (µg.m⁻².h⁻¹) as an approximation of the global warming potential value, Fm is the carbon gas flux (µg.m⁻².h⁻¹), GWP is the potential warming value of global carbon gas, namely the conversion value of emissions per mole of CH₄ gas equivalent to 25 times CO₂-eq emissions for 100 years (IPCC, 2001).

3. Results and Discussion

Physical Characteristics of Research Sites

Observation results on the physical characteristics of the environment densely populated areas (PP) and the populated areas (JP) are presented in table 2.

Table 2. Physical characteristics of the coastal settlement area of Mawasangka District

Parameters	Site of observations	
	Densely populated (PP)	Sparsely populated (JP)
Types of substrate	Muddy sand	Rocky sand
Temperature (°C)	29	28,5
Salinity (psu)	32	32
Marine debris	found	not found

As seen on the Table, the two residential locations have different physical characteristics. Densely populated residential areas have a muddy sand substrate type and higher temperatures (29 °C). In addition, this area also has many piles of both organic and inorganic waste. Meanwhile, sparsely populated areas have different substrates (rocky sand) and lower temperatures (28.5 °C) with no piles of waste.

Carbon Gas Concentration

The concentration of CO₂ gas in densely populated areas (PP) is 518.54 ± 68.17 ppm, greater than the concentration of CO₂ gas in sparsely populated areas (JP) of 417.52 ± 56.10 ppm (Figure 3). The ANOVA test resulted in gas concentration values in the two areas with significantly different gap (p-value = 0.000067 <0.05).

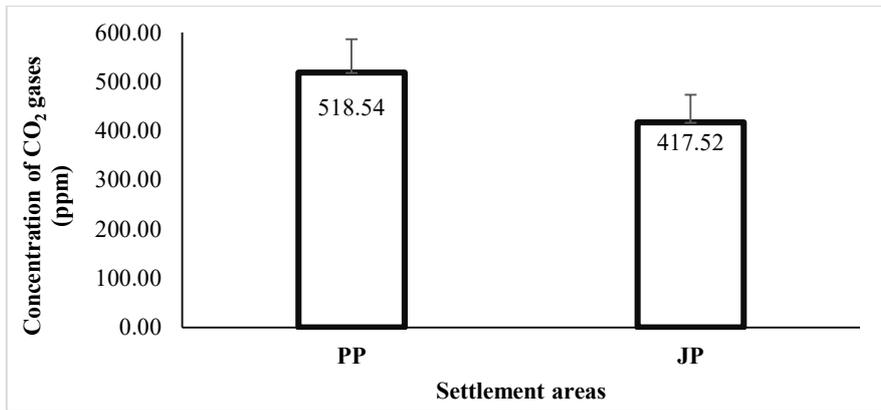


Figure 3. The concentration of CO₂ gas in densely populated (PP) and sparsely populated (JP) areas

In the PP area, the highest concentration was found at t = the 30s, which ranged from 470.48 – 680.19 ppm (Figure 4a), while in the JP area, the greatest concentration was found at t = 60s with values ranging from 344.32 – 623.69 ppm (Figure 4b).

According to Rahman et al. (2018) and Rahman et al. (2020b), CO₂ gas formed in wetlands increases with increasing organic matter through the hydrolysis reaction of glucose to acetic acid.

Organic matter in the PP area can be identified from the waste, as presented in Table 2. In addition, the muddy sediment in the PP tends to form CO₂ gas than the rocky sand sediments in the JP area. As explained by Kesaulya et al. (2023) and Tubalawony et al. (2024), the concentrations of greenhouse gases such as CO₂ and CH₄ are higher in muddy sediments than in sandy sediments.

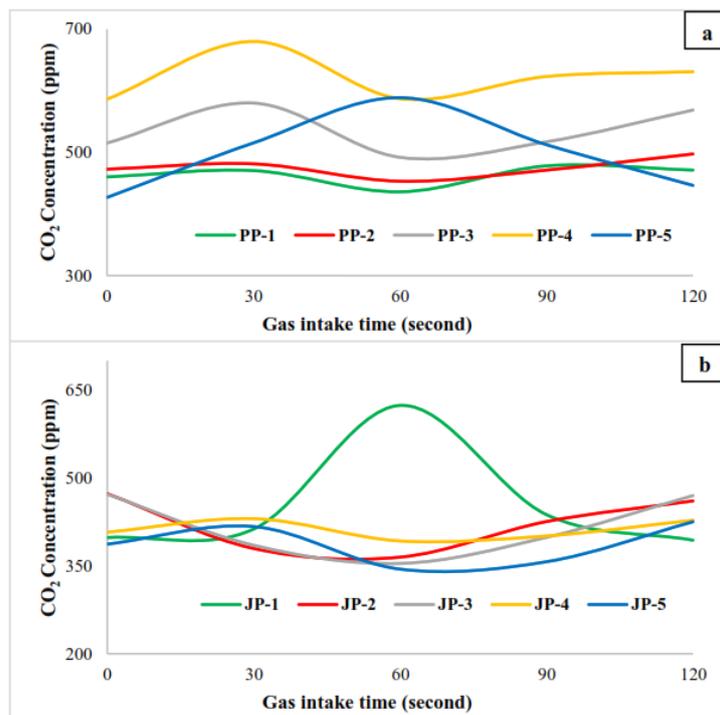


Figure 4. Variation of CO₂ gas concentration at each gas collection time interval: (a) densely populated areas (PP-1 – PP-5); (b) sparsely populated areas (JP-1 – JP-5).

The CH₄ concentration in the PP area ranged from 1.93 ± 0.036 ppm, slightly higher than in the JP area (1.85 ± 0.008 ppm) (Figure

5). However, ANOVA results indicated no significant difference between the two areas ($p = 0.1721 > 0.05$).

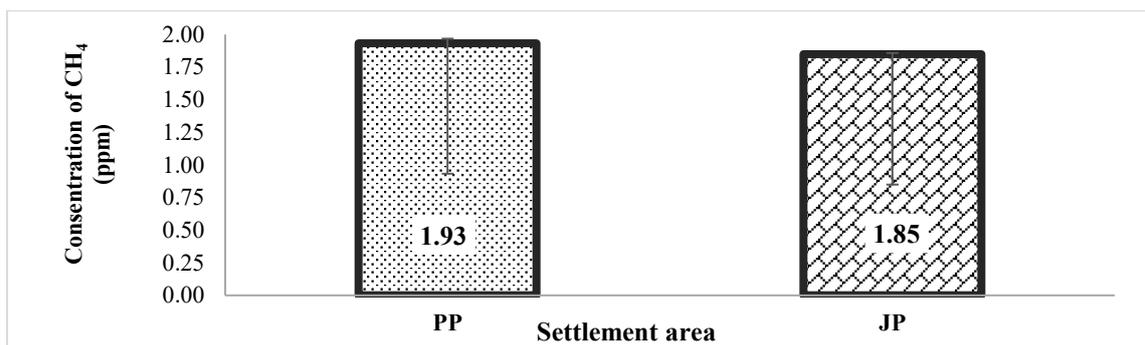


Figure 5. The concentration of CH₄ gas in densely populated (PP) and sparsely populated (JP) areas

In the PP area, the highest CH₄ concentration was observed at $t = 60$ s (PP-2) with 2.25 ppm, while the lowest occurred at $t = 0$ s (PP-1) with 1.39 ppm (Figure 6a). Similarly, in the JP area, the

highest concentration was also recorded at $t = 60$ s (JP-2) with 2.13 ppm, whereas the lowest was found at $t = 90$ s (JP-3) with 1.63 ppm (Figure 6b).

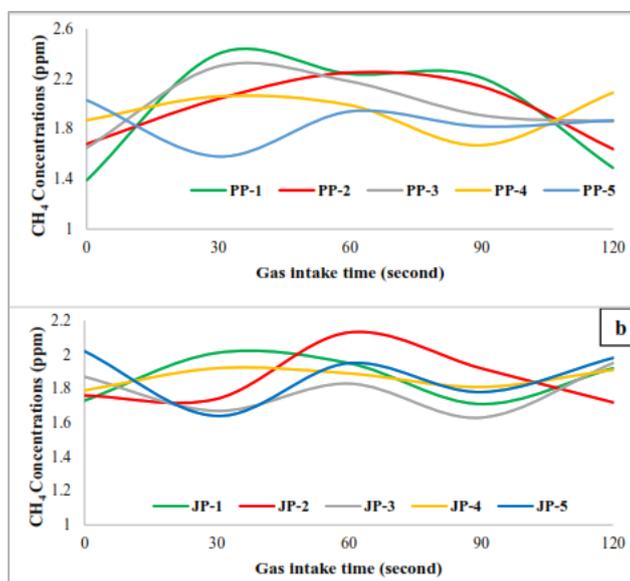


Figure 6. Variation of CH₄ gas concentration at each time interval for gas collection: (a) densely populated areas (PP-1 – PP-5); (b) sparsely populated areas (JP-1 – JP-5).

Carbon Gas Emissions

Overall, residential area emissions averaged 9.39 ± 4.55 mg·m⁻²·h⁻¹. CO₂ emissions were substantially higher in the PP area (13.36 ± 2.04 mg·m⁻²·h⁻¹) than in the JP area (5.42 ± 1.74 mg·m⁻²·h⁻¹) (Figure 7). The higher emissions in PP are attributed to greater organic matter input, as residents frequently dispose of domestic waste, such as food scraps, which contributes to silt deposits rich in decomposed organic material. This result aligns with Rahman et al. (2018), who found that CO₂ emissions in the

Tallo River, Makassar, were higher in areas polluted by organic waste.

The single-factor ANOVA test showed a significantly difference in mean CO₂ emissions between the two areas (P -value = 0.00071 < 0.05). The difference in emissions in the two areas is consistent across all observation points (PP-1 to PP-5 and JP-1 to JP-5) (Figure 7). Hence, effective waste management prior to the waste discharge is needed to reduce water pollution from increased CO₂ gas emissions.

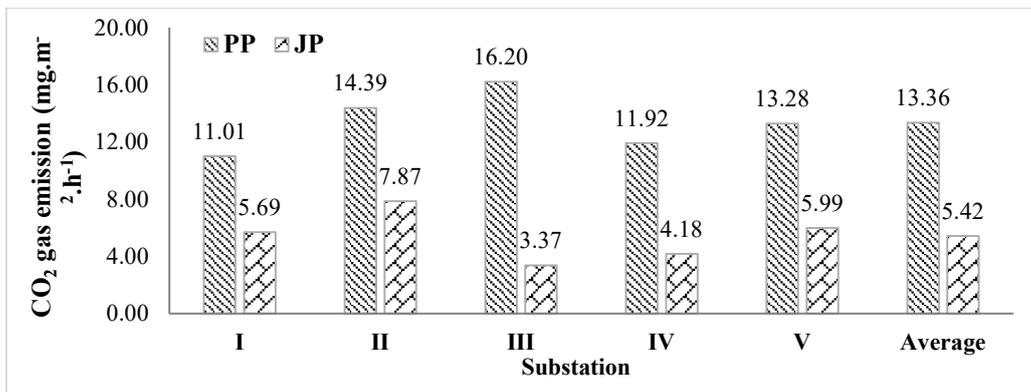


Figure 7. CO₂ gas emissions in residential areas in Mawasangka District – Central Buton: PP = densely populated; JP = Sparsely populated. The two areas (PP and JP) also showed different average

CH₄ emission values. Emissions in the PP area were 0.036 mg.m⁻².h⁻¹, significantly higher (P-value = 0.03 < 0.05) than in the JP area of 0.014 mg.m⁻².h⁻¹ (Figure 8). However, the difference was smaller than that observed for CO₂ emissions, as reflected in the

comparable standard deviations of the two regions of 0.0105 and 0.0102, respectively. The CH₄ emissions in the PP-5 area were found lower than CH₄ emissions in the JP-5 area (0.022 mg.m⁻².h⁻¹ < 0.029 mg.m⁻².h⁻¹) (Figure 8).

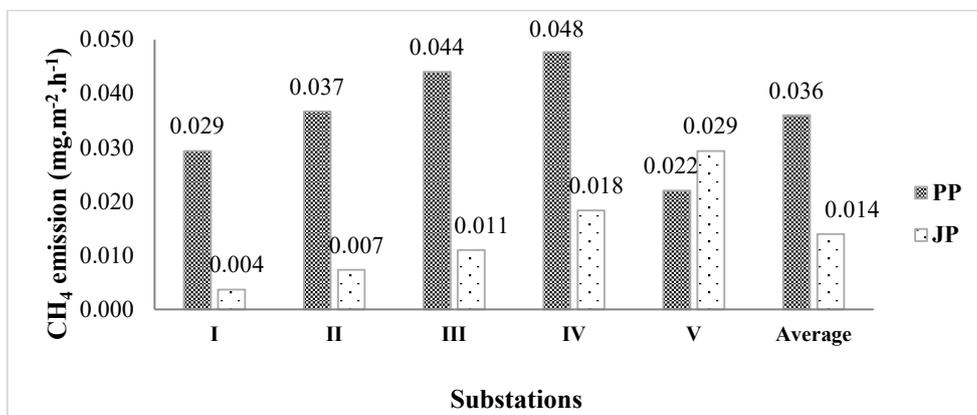


Figure 8. CH₄ gas emissions in residential areas; PP = densely populated; JP = sparsely populated.

Global Warming Potential of Carbon Gas

The GWP value in the PP area was 14.403 mg CO₂-eq m⁻².h⁻¹, greater than the GWP value in the JP region of 5.822 mg CO₂-eq m⁻².h⁻¹. The average GWP value for residential areas was 10.113 mg CO₂-eq m⁻².h⁻¹ (Table 3) with greater significance compared to the GWP of mangrove ecosystems in Benggai Bay - India of 2.06 mg CO₂-eq m⁻².h⁻¹ (Biswas et al., 2007) and Florida mangroves of

1.61 mg CO₂-eq m⁻².h⁻¹ (Cabezaz et al., 2017). The settlements in the coastal area of the Mawasangka Subdistrict significantly contributed to the higher greenhouse gas emissions in the atmosphere, especially CO₂ gas. However, the GWP of CH₄ gas was only 0.9 mg CO₂-eq m⁻².h⁻¹ that was smaller than the IPCC standard (IPCC, 2001) of 1 mg CO₂-eq m⁻².h⁻¹.

Table 3. The potential for global warming (GWP) from the residential area of Mawasangka District - Central Buton

Locations	Emissions (mg.m ⁻² .h ⁻¹)		GWP (mg CO ₂ -eq m ⁻² .h ⁻¹)
	CO ₂	CH ₄	
PP	13.36	0.036	14.403
JP	5.42	0.014	5.822
Average	9.39	0.025	10.113

Methane gas (CH₄) is formed from methanogenic processes (Rahman et al., 2020b), in which concentrations and greenhouse gas emissions become significant under anaerobic conditions (Liu et al., 2024). Based on the concentration, emission, and GWP values obtained in this research, the CH₄ gas formed in research

sites is within normal limits. However, total greenhouse gas emissions and GWP from carbon gases need to be intensively controlled.

4. Conclusion

The average concentration of CO₂ gas in the two residential areas (PP and JP) was significantly different (P -value = 0.000067 < 0.05), while the average concentration of CH₄ gas was not significantly different (P -value = 0.1721 > 0.05). CO₂ emissions in densely populated areas (PP) are 13.36 mg.m⁻².h⁻¹ and higher than sparsely populated areas (JP), which are 5.42 mg.m⁻².h⁻¹. These values are significantly different (P -value = 0.00071 < 0.05). Meanwhile, CH₄ gas emissions in the PP area (0.036 mg.m⁻².h⁻¹) are greater than those in the JP area (0.014 mg.m⁻².h⁻¹). These values are also significantly different (P -value = 0.03 < 0.05). The PP area GWP value is 14.403 mg CO₂-eq m⁻².h⁻¹. This value is greater than the GWP value in the JP region, which is 5.822 mg CO₂-eq m⁻².h⁻¹. It indicates that settlements in the coastal area of the Mawasangka district significantly contribute to increasing greenhouse gas emissions, especially CO₂, influenced by high population density and the sediment characteristics of the region. Total greenhouse gas emissions and GWP from carbon gases need to be controlled.

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