Methane emission from rice paddies: Need for a downward revision of global estimate

CARBON dioxide, CH_4, CFC-11, CFC-12 and N_2O are the most important greenhouse gases that are affected by human activities[1]. Among these, CH_4 is the only gas which directly affects the tropospheric chemistry, and forms a part of the highly interactive chemical system that largely determines the background concentration of the hydroxyl radical, which is the most important oxidizing gas in the troposphere[1]. Rice paddies are considered to be among the most important sources of atmospheric CH_4, contributing from 60–100 Tg per year[2–5]. Estimates, however, are beset with many assumptions[6]. Our analysis of published results indicates that CH_4 contribution from rice paddies has been *substantially overestimated*.

The frequency distribution of CH_4 emission rates ($N = 350$) compiled from a variety of studies *in different* regions[7–35] was markedly skewed towards left (Figure 1, curve a). In this and the following analyses, all data points are given equal weightage irrespective of the time of measurement, treatment or region. Thus, no attempt was made to integrate the CH_4 flux for the whole season, and all values were converted to mg $CH_4\ m^{-2}h^{-1}$. About 67% values were $< 16\ mg\ m^{-2}h^{-1}$; of these, 54% values were $\leq 8\ mg\ m^{-2}h^{-1}$. Values greater than 40 mg $CH_4\ m^{-2}\ h^{-1}$ were mostly from pot experiments[9–12] and a few from field experiments[14,30,33], involving high inputs of chemical fertilizèrs/paddy straw/horse manure. In these pot experiments inputs included 12–24 g rice straw per 3 kg of soil[9–12]. The field experiments had inputs of 30 t ha^{-1} of *Sesbania rostrata* or 2 t ha^{-1} of rice straw[14]; 710 kg ha^{-1} NH_4HCO_3 + 30 t ha^{-1} horse manure[30]; 694 kg ha^{-1} K_2SO_4/KCl + 1042 kg ha^{-1} rapeseed cake or only 1042 kg ha^{-1} rapeseed cake[33]. Curve b in Figure 1, illustrates the frequency distribution ($N = 326$) after these values were excluded. Curve c in Figure 1, represents the distribution of emission rates ($N = 280$) when all data from pot experiments[9–12, 34], including lower values (in addition to those from high inputs in refs. 14, 30, 33), were excluded.

Simple averages from data in Figure 1 (curves a–c) ranged from 12.29 to 14.89 mg $CH_4\ m^{-2}\ h^{-1}$ and were associated with high standard deviation values (Table 1). These averages compare with 12.92 (ref. 3), 14.58 (ref. 36), 9.99–33.33 (ref. 7) and 21 mg $m^{-2}\ h^{-1}$ (ref. 5) reported earlier.

Based on the FAO statistics, Neue and Roger[37] estimated a harvested rice area of 73.26 m ha for irrigated rice, 38.95 for rain-fed rice and 11.45 for deep-water rice (total $1.236 \times 10^{12}\ m^2$). Aselmann and Crutzen[3] have used the value $1.31 \times 10^{12}\ m^2$ for rice land area. Globally, 60% of the harvested area is managed under a triple cropping system, 15% is double cropped and 25% is cropped once a year[5]. CH_4 emission period ranges from 85 to 126 days

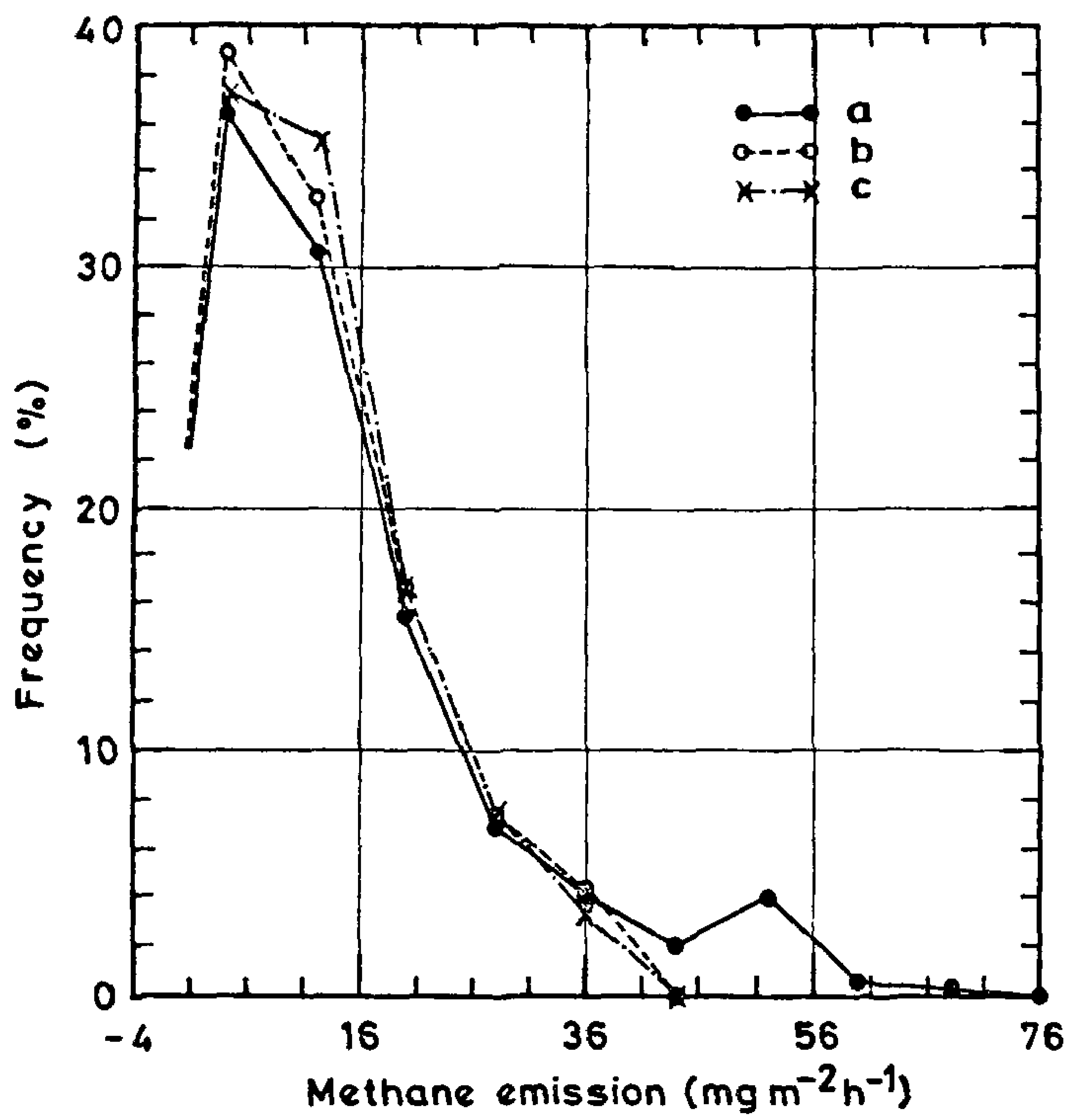

Figure 1. Frequency polygon for CH_4 emission rates. Each data point is an average of several but variable number of replicates. ***a***, all data, ***b***, exceptionally high values due to high inputs of chemical fertilizer/organic matter excluded; ***c***, values from all pot experiments excluded in addition to exceptionally high values from field experiments due to high inputs of fertilizer/organic matter.

Table 1. Calculated CH_4 emission from rice paddies on the basis of data in Figure 1

	Emission rate (mg CH_4 m^{-2} h^{-1})	Annual emission (Tg CH_4 yr^{-1})
All data		
Simple average	14.89 (±12.95)	49.13
Geometric mean	9.32	30.76
Exceptionally high values removed[1]		
Simple average	12.29 (± 8.88)	40.58
Geometric mean	8.24	27.19
Values for all pot experiments removed[2]		
Simple average	12.34 (± 8.14)	40.72
Geometric mean	8.97	29.60

Values in parentheses are standard deviations.
[1]Values from experiments with heavy doses of chemical fertilizers and paddy straw/horse manure were excluded. Most of these were pot experiments.
[2]Values from all pot experiments involving chemical fertilization and organic matter amendment were excluded.

around the world[6] and averages 105 days. Using 1.31×10^{12} m^2 rice cultivation area, a CH_4 emission period of 105 days and average emission rates, the total global emission varies from 40.58 to 49.13 Tg yr^{-1} (Table 1). Because of the pronounced skewness in the data and high standard deviations associated with simple averages, it would seem preferable to use geometric means. Based on geometric means, the total CH_4 emission varies from 27.19 to 30.76 Tg yr^{-1} (Table 1).

Inclusion of the data from artificial pot experiments or from field experiments with very high inputs of organic matter in calculations of global emission may not be realistic. A recent review indicated that the CH_4 flux response to the application of fertilizer or/and organic matter ranged from negligible to dramatic (–75 to +6857% compared to control), and varied from year to year, among periods within a growing season, and from treatment to treatment[38]. Additionally, if harvested wetland rice area of 1.236×10^{12} m^2 is used as calculated by Neue and Roger[37], the global estimate reduces to 25.68–27.84 Tg CH_4 yr^{-1}. We suggest that these values could be considered a reasonable estimate until all rice-growing regions and rice ecologies are adequately covered by flux measurements. These estimates depend much on the CH_4 emission period, which may vary substantially in different geographic regions. Assuming a 30 d emission period, as argued by Sinha[39], the estimate for global emission reduces to 7.34–7.95 Tg yr^{-1}. This estimate compares with 7.08 Tg yr^{-1} assessed by Sinha[39] on the basis of rice yield and 30 d CH_4 emission period. Thus, there is a need for substantial reduction in the global estimate of CH_4 emission from rice paddies.

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ACKNOWLEDGEMENT. This study was funded by the Ministry of Environment and Forests, Government of India, New Delhi.

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