

REGULARITY AND ESTIMATION OF METHANE EMISSION FROM MARSHLAND IN THE SANJIANG PLAIN^①

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ABSTRACT: The regularity of CH₄ emission from marshland in the Sanjiang Plain was studied by sampling in the open field and analyzing under laboratory condition, the annual emission amount is also estimated. By Grey Relatively Analysis we know that the soil temperature in the 10 cm depth of grass root layer is close related with CH₄ emission. CH₄ emission has different kinds of diurnal emission modes: before dawn maximum mode, night maximum mode and irregular fluctuation mode. The seasonal variation trend of CH₄ emission rates is going up steadily from May to August and dropping down from September, the maximum lies behind the maximum of temperature. CH₄ emission rates of different marshland types are different, the CH₄ emission rate of *Glyceria spiculosa* – *Carex* marshland is always higher than that of *Carex lasiocarpa* marshland. The paper also studies the difference of CH₄ emission rates in different managing modes and analyzes the emission rates between China and U. S. A. The result shows: the average value of CH₄ emission rate is 17.26mg/(m²·h), the annual amount of CH₄ emission is about 0.75Tg.

KEY WORDS: Sanjiang Plain, marshland, methane emission, diurnal variation, seasonal variation

I. INTRODUCTION

CH₄ is one of the greatest abundant organic compounds in volatile hydrocarbon of atmosphere, it has an important influence on the energy balance of earth system and the climate formation. CH₄ is also chemically active gas and can be oxidized to form a series of hydroxides and hydrocarbons, acts as an important role in the chemical transformation of many atmospheric ingredients. The studies show: CH₄ concentration in atmosphere always kept between 0.6 mg/

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kg and 0.8 mg/kg during the period from 3000a B. P. to 150a B. P. (Ma *et al.*, 1995). But since the Industrial Revolution, CH₄ concentration in the atmosphere has gone up from 0.88 mg/kg to 1.7 mg/kg. From 1945 to 1985, the average increasing rate of CH₄ in the atmosphere is 1%, after 1986 it dropped down to 0.9%. In the 1980s, many scholars began to research the sources and sinks of CH₄ when one found the obvious increase of CH₄ concentration in the atmosphere. According to the measurements, 80 percent of the amount of CH₄ in the atmosphere comes from biological sources on the earth, the marshlands in the Northern Hemisphere are regarded as one of the most important factors in CH₄ emission sources (Robert *et al.*, 1985).

China has large area of marshland, especially the Sanjiang Plain, the marshland covers 47 percent of the plain. So the studies on the CH₄ emission regularity from marshland in the Sanjiang Plain can provide a basis for the estimation and future variation trends of CH₄ emission amount in China, even all over the world. On the other hand, we can study the mutual relation among environmental factors from the aspect of the atmosphere chemistry in order to provide a scientific basis for the rational use and conservation of marshlands.

II. OBSERVATION IN SITE ON METHANE EMISSION FROM MARSHLAND

The Sanjiang Plain was selected to estimate the CH₄ emission amount in the regional marshland and the observing position is located in the west of Honghe Farm which lies in the hinterland of the Sanjiang Plain Ecological Test Station of Mires and Wetlands in the Sanjiang Plain, the Chinese Academy of Sciences.

1. The Description of the Estimation Area and the Observing Position

The Sanjiang Plain lies in the northeast of the Heilongjiang Province, its topography is high in the southwest and low in the northeast. Mire distributing rate reaches 21 percent and forms an important kind of landscapes in this area. The observing position lies in the center of the observing field of the Ecological Test Station of Mires and Wetlands in the Sanjiang Plain. The observing field is an integrate confluence area, with an area of 21.46 hm², in which the marshland area covers 7.76 hm², making up 36.1 percent of the total confluence area. The field is low and even, there are many kinds of mires and it is very typical in the Sanjiang Plain. The steady sampling position locates in the typical *Carex lasiocarpa* marshland, comparing types include *Carex lasiocarpa*, *Glyceria spiculosa* – *Carex*, *Carex schmidtii*, *Carex*. sp – *Calamagrostis angustifolia*, *Phragmites communis* – *Calamagrostis angustifolia* marshland.

2. Sampling and Measuring Method

Observing and sampling were arranged from June to September in 1995, from May to

September in 1996. Sampling place was selected by square wooden frame which is fixed and flooded, some natural plants growing in the frame. There is a wooden bridge built around the place. We take static box and manual sampling technology. While sampling we also observed temperature of the inside box, water, air and the grass root layer, the depth of accumulated water, the height of plant bodies, covering degree of plants, weather, etc. CH₄ concentration is measured by meteorological chromatogram instrument(SQ-208) under laboratory condition. The calculating formula on the CH₄ emission rate is:

$$F = 0.714 * H * \Delta C / \Delta T * 273 / (273 + T)$$

where F —CH₄ emission rate(mg/(m²·h));

H —height of the box(m);

$\Delta C / \Delta T$ —variation rate of CH₄ concentration;

T —the temperature inside box(℃).

III. GREY RELATIVE ANALYSIS ON THE OBSERVING DATA

We got 130 values of CH₄ emission flux and 1000 values of relative factors. We can find the most relative factors between CH₄ emission rates and environmental factors by Grey Relative Analysis(Yi *et al.*, 1992). Data processing is as follows:

1) Primitive data:

CH₄ emission rate(x_0) =

$$\begin{vmatrix} (x_0(1), x_0(2), x_0(3), x_0(4), x_0(5), x_0(6), x_0(7), x_0(8), x_0(9)) \\ (6.72, 12.70, 28.70, 22.90, 10.18, 11.98, 24.80, 29.48, 7.77) \end{vmatrix}$$

Air temperature in the 100 cm height(x_1) =

$$\begin{vmatrix} (x_1(1), x_1(2), x_1(3), x_1(4), x_1(5), x_1(6), x_1(7), x_1(8), x_1(9)) \\ (23.53, 26.11, 22.73, 18.15, 17.53, 21.12, 23.34, 19.76, 15.94) \end{vmatrix}$$

Temperature inside box(x_2) =

$$\begin{vmatrix} (x_2(1), x_2(2), x_2(3), x_2(4), x_2(5), x_2(6), x_2(7), x_2(8), x_2(9)) \\ (27.95, 28.26, 29.86, 22.59, 24.38, 29.48, 31.36, 23.73, 18.32) \end{vmatrix}$$

Average water temperature(x_3) =

$$\begin{vmatrix} (x_3(1), x_3(2), x_3(3), x_3(4), x_3(5), x_3(6), x_3(7), x_3(8), x_3(9)) \\ (18.63, 22.71, 20.93, 16.21, 15.07, 18.63, 23.24, 18.89, 14.50) \end{vmatrix}$$

Grass root layer temperature in 5 cm depth(x_4) =

$$\begin{vmatrix} (x_4(1), x_4(2), x_4(3), x_4(4), x_4(5), x_4(6), x_4(7), x_4(8), x_4(9)) \\ (17.20, 21.43, 19.71, 15.93, 13.90, 17.70, 21.68, 18.20, 14.40) \end{vmatrix}$$

Grass root layer temperature in the 10 cm depth(x_5) =

$$\begin{vmatrix} (x_5(1), x_5(2), x_5(3), x_5(4), x_5(5), x_5(6), x_5(7), x_5(8), x_5(9)) \\ (15.70, 20.00, 18.54, 15.29, 11.50, 15.31, 20.67, 17.26, 13.70) \end{vmatrix}$$

Grass root layer temperature in 15 cm depth(x_6) =

$$\left| \begin{array}{l} (x_6(1), x_6(2), x_6(3), x_6(4), x_6(5), x_6(6), x_6(7), x_6(8), x_6(9)) \\ (15.00, 18.57, 17.66, 14.78, 10.36, 14.88, 19.57, 16.64, 13.20) \end{array} \right|$$

- 2) Initial value processing for primitive data: $x_0, x_i (i = 1 \text{ to } 6)$
- 3) Calculating difference orders: $\Delta_0 i (i = 1 \text{ to } 6)$
- 4) Find out the maximum difference (Δ_{\max}) and the minimum difference (Δ_{\min})
- 5) Calculating related coefficient by the formula:

$$A_{0i}(k) = (\Delta_{\min} + d \Delta_{\max}) / (\Delta_0 i(k) + d \Delta_{\max}) \quad (d = 0.5, k = 1 \text{ to } 9)$$

- 6) Calculating related degree by the formula:

$$R_{0i} = 1/n [A_{0i}(1) + A_{0i}(2) + \dots + A_{0i}(9)]$$

the results are as follows:

$$R_{01} = 0.6189 \quad R_{02} = 0.6289 \quad R_{03} = 0.6622$$

$$R_{04} = 0.6644 \quad R_{05} = 0.6722 \quad R_{06} = 0.6566$$

- 7) Arranging the related orders:

$$R_{05} > R_{04} > R_{03} > R_{06} > R_{02} > R_{01}$$

The above conclusion shows: CH₄ emission rate first is closely related with the temperature in 10-cm depth of grass-root layer, second with the temperature in 5-cm, 15-cm depth of grass-root layer, then with water temperature, temperature inside box, final with air temperature.

IV. REGULARITY STUDY ON METHANE EMISSION

1. The Diurnal Variation of CH₄ Emission from Marshland in the Sanjiang Plain

1.1 Contrast between different diurnal emission modes of CH₄

Carex lasiocarpa marsh, accompanied by *Megan thestrifoliolate* and *Caltha palustris* etc., is the major observing object. During the whole growing season of *Carex lasiocarpa*, CH₄ production, oxidization, transmitting and emission change with the changes of environmental factors around the vegetables. Through observing in different seasons in two years we found the diurnal variation modes of CH₄ emission from marshland in the Sanjiang Plain (Fig. 1).

Before-dawn maximum mode: The regularity mainly occurs during the flowering (the middle and last ten days in May) or the fruit-bearing period (June, the first ten days in July) under the normal weather (Fig. 1a, 1d). We can obviously see the peak value at 3 o'clock is much relative to the temperature change, CH₄ emission rate is the highest when temperature is the lowest. Because these periods are the vigorous growing seasons of vegetables, vegetable respiratory metabolism is strong, when temperature is high, vegetables shut stomas to prevent moisture content from losing, so the main transmitting channels from plants to atmosphere are blocked up. As the air temperature falling at night, CH₄ in the plant bodies begins to emit into the atmosphere while the plants' stomas open. The results show the highest value of CH₄ emission at

the before dawn. Shangguan Xingjian et al. also reported the same regularity in the rice field (Shangguan *et al.*, 1993).

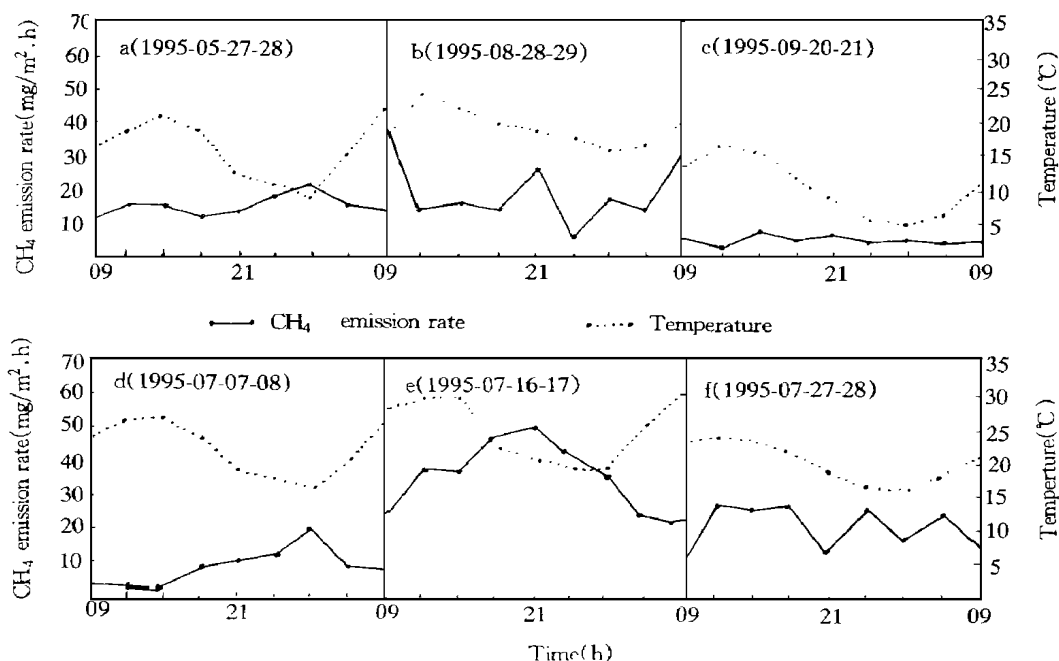


Fig. 1 The diurnal variation of methane emission

Night maximum mode: Shown as the Fig. 1e, the peak value appears at 21 o'clock, not the time when temperature is lowest. Because the middle ten days in July is the mature period of *Carex lasiocarpa*, vegetable air tissues are well developed, strong sunlight only shut part of the stomas. Provided the environment is suitable, the stomas will completely unblock when night falls and CH₄ emission rate will reach peak value. This regularity also occurs in the observation of the rice field in the suburb of Changchun City^①

Irregular fluctuation mode: It occurs when the weather changes, such as rainy or very low temperature, as shown in Fig. 1b, 1c, 1f. The data in Fig. 1b, 1f were obtained under the cloudy-drizzle condition. The data in Fig. 1c were obtained under the air temperature. We think the low temperature influence CH₄ production, oxidization and its transmitting passages, so it causes the random of the transmitting efficiency and the irregularity of CH₄ emission. Alike in rainy day, the temperature is low and variation is irregular and has no obvious influence on CH₄ production and transmission in soil, so the CH₄ produced in soil may emit to air irregularly. This phenomenon was also found in the study on CH₄ emission in the rice field in Hangzhou City.

① Wang Dexuan: CH₄ emission from the rice field in Jilin Province, 1996.

1.2 Characteristic value analysis of CH4 diurnal emission

Based on the observing data in 1995 and 1996, when the average diurnal value of CH4 emission rate is the highest, the diurnal variation range is the biggest. On the contrary, it is opposite (Table 1).

Table 1 Characteristic value of diurnal variation of CH4 emission from marshland

Year Month Day	Maximum – Minimum Average value of daily emission	Diurnal changing range Ratio	Characteristic value	Weather condition	Fertility period
1995– 07 7– 8	19. 18– 1. 40 7. 88	17. 78 13. 7	One humped mode	Cloudy	Fruit bearing Period
1995– 07 27– 28	29. 41– 7. 38 22. 18	21. 85 3. 96	Irregular mode	Clear cloudy	Middle stage of mature period
1995– 08 28– 29	30. 41– 5. 51 19. 44	24. 90 5. 52	Irregular mode	Overcast rainy cloudy clear	Later stage of mature period
1996– 05 27– 28	20. 95– 11. 67 16. 15	9. 28 1. 80	One humped mode	Cloudy clear	Florescence
1996– 07 16– 17	50. 98– 23. 86 39. 72	27. 12 2. 14	One humped mode	Clear	Early stage of mature period
1996– 09 20– 21	7. 48– 0 4. 73	7. 48 7. 48	Irregular mode	Overcast cloudy clear	Withered and yellow period

Under normal weather, the peak value of CH4 diurnal emission appears at 3 o’ clock before dawn or at 21– 22 o’ clock at night, the minimum at 15– 18 o’ clock in the afternoon, some appear at 6– 7 o’ clock in the morning. If it is rainy or low temperature, the maximum is the same. So we can see the difference between fine day and cloudy day is obvious on diurnal variation of CH4 emission. In fine day it is regular, cloudy day irregular.

2. The Seasonal Variation of CH4 Emission in Marshland

2.1 The annual variation of CH4 emission in Carex lasiocarpa marshland

Through 2-year observing and sampling (1995, 1996) on CH4 emission in the whole growing season of *Carex lasiocarpa*, we got the same result shown as Fig. 2. In May, temperature begins to go up and the frozen ground melts gradually, so CH4 which didn’t emit in the last year in the soil now begins to emit into air. In May, *Carex lasiocarpa* is in florescence, the deep soil temperature is still low, so CH4 producing and emission rates are not high, the melting of the frozen ground certainly increases the net amount of CH4. *Carex lasiocarpa* is in fruit-bearing period in June, although temperature has gone up, yet the rainfall is low and

there is little accumulated water, which doesn't fit the growth of bacteria which produces CH₄, so the production rate of CH₄ is still low. But the air tissues are well developed and the frozen ground melts further, the net emission amount of CH₄ in June is little higher than in May. In July it comes into rainy season and temperature is the highest in a year, there is much

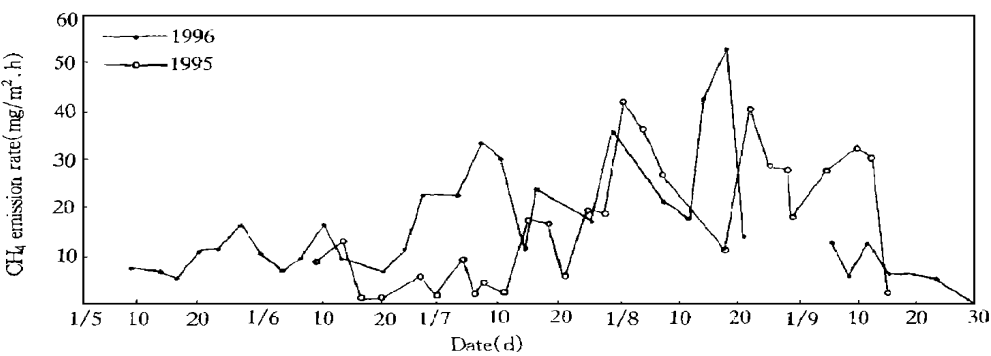


Fig. 2 The annual variation trend of CH₄ emission from *Carex lasiocarpa* marshland

accumulated water in marshland, which produces a perfect anaerobic environment for the production of CH₄. Meanwhile, vegetables have gone into mature period, so the net emission rate in July is higher than that in June. In August, temperature begins to drop down little, but vegetables have well developed and there is good condition of accumulated water, so CH₄ emission rate reaches the highest in a year. After September, temperature drops further and vegetables begin to wither, so the production rate of CH₄ is low and the net emission rate decreases.

2.2 The relation between average monthly emission rate of CH₄ and average monthly temperature

Fig. 3 shows the relation in 1995 and 1996. We can reach a conclusion: the maximum of CH₄ emission rate lies behind the maximum of temperature. Temperature goes up from May to July and drops down in August while the average monthly emission rate of CH₄ goes up from

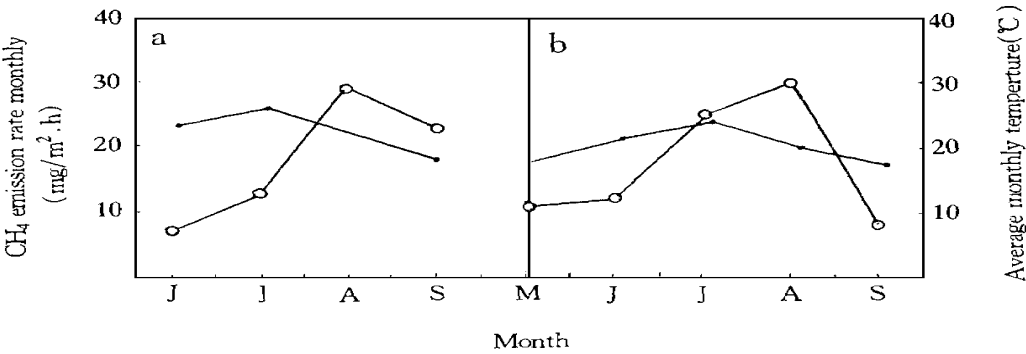


Fig. 3 The relation between CH₄ emission rate and average monthly temperature

May to August and decreases in September. In July, the average temperature is the highest while the maximum of CH₄ emission rate occurs in August. It shows that CH₄ emission does not synchronize with change of temperature. As the air temperature reaches the highest in a year, the soil temperature does not, the soil temperature reaches the highest, which can provide a perfect temperature for bacteria and produce CH₄, so the production rate of CH₄ is the highest. Moreover, all conditions reach the most perfect state, leads causing the net emission amount of CH₄ to reach the maximum.

3. CH₄ Emission from Different Kinds of Marsh

Due to the difference in micro landforms in test stations, the marshland vegetable types, vegetable transmission capacity, accumulated water conditions, grass root layer moisture content, soil organic matters and pH value are different, which would lead to different CH₄ production and emission rates. We selected *Glyceria spiculosa*–*Carex*, *Carex Schmidtii*, *Carex* – *Calamagrostis angustifolia* and *Phragmites communis* – *Calamagrostis angustifolia* marsh types, etc, to observe for contrast while selecting *Carex lasiocarpa* marsh as the main observing object in the open field. The result shows as Fig. 4, CH₄ emission rate in *Glyceria spiculosa*–*Carex* marsh is always higher than that in *Carex lasiocarpa* marsh due to the higher stems, density and well developed air tissue of the former. Accumulated water between “hummock” in *Carex schmidtii* marsh leads to the turns of low and high values of CH₄ emission rates which decided by sampling positions. Generally the emission rate in *Carex* – *Calamagrostis angustifolia* and *Phragmites communis* – *Calamagrostis angustifolia* marsh is the lowest due to their landform positions and less organic matter. But several high CH₄ emission rates have been shown in the result due to different degrees of accumulated water, it is related with their own developed air tissues.

4. Difference for CH₄ Emission under Different Management Means

During observation, we dealt with the sampling places by the following three different ways:

4.1 Flooding grass into water state

Trading vegetables into water for several days, then restoring several days in natural condition, only less vegetables exposed out water. Through observation and sampling, the result shows: CH₄ emission rate drops from 4.12 to 0.18 mg/(m²•h) due to the decrease of the transmission passage.

4.2 The CH₄ emission condition after cutting grass

There are 5-cm height plant stems left after cutting grass. The result shows CH₄ emission rate is higher in the same day [9.59 mg/(m²•h)] than that before cutting grass [9.26 mg/(m²•h)], After half a month, CH₄ emission rate is still higher [27.47 mg/(m²•h)], and also

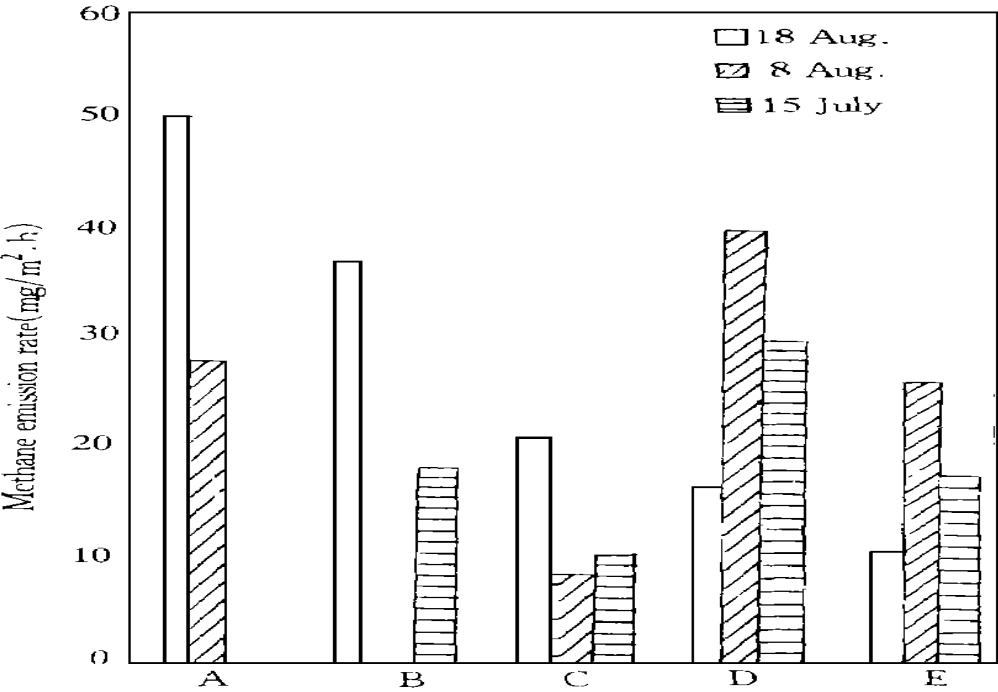
higher than that in the third day later [26.04 mg/(m²•h)] that grass is in natural condition. The reason is that plant stomas become larger after cutting grass and promote CH₄ emission.

4.3 Standing withered bodies condition

By removing fresh grass and remaining withered bodies and accompanying plants, but other conditions didn ’ t change during observing period , we got the result: CH₄ emission rate [19.09 mg/(m²•h)] is lower, corresponding 28.62 mg/(m²•h) before removing fresh grass.

5. CH₄ Emission from Different Gathering Water Condition in the Same Plants

The test shows: CH₄ emission rate is very low or nothing in no gathering water condition [0– 0.18 mg/(m²•h)], the grass root layer is full of water if there is a CH₄ emission rate. It is possible to have no CH₄ emission even if there is little gathering water (2– 3 cm), which is decided by weather condition and environment factors such as air temperature, wind speed, evaporation and sunshine. There will be a special value of CH₄ emission [7.38– 44.20 mg/(m²•h)] when the depth of gathering water reaches over 6cm; but there is no linear relation between them. That is to say, CH₄ emission rate is not only decided by water condition, but also related to air temperature, water temperature, plant height and growing stage.



A: *Phragmites communis*-*Calamagrostis angustifolia*
 B: *Carex* - *Calamagrostis angustifolia*
 C: *Carex schmidtii* D: *Glyceria spiculosa*-*Carex* E: *Carex lasiocarpa*

Fig.4 The difference of CH₄ emission from five kinds of mire

6. Contrast and Analysis on CH₄ Emission Rates Among Marshlands at the Same Latitude

Contrasting CH₄ emission rates in marshlands between “ Ecological Test Station of Mires and Wetlands in the Sanjiang Plain”(47°35′ N, 133°31′ E) and “ Marcell Station in Minnesota, in U. S. A”(47°32′ N, 93°28′ W), we can obtain the similarities and differences between the two areas by drawing histogram(Fig. 5). The histogram of the Sanjiang Plain is based on 128 data obtained in 2 years while that of U. S. A. is based on 51 data obtained in 3 years. The average CH₄ emission rate of marshland in the Sanjiang Plain is 17.26 mg/(m²•h) , the average of the 128 data is 16.35 mg/(m²•h) , correspondingly, the America’s are 14.02 mg/(m²•h) and 7.02 mg/(m²•h). So their differences show that the rate in the Sanjiang Plain is a little higher than that of the mid- and- north part of America. Viewed from the obtained data, the varia

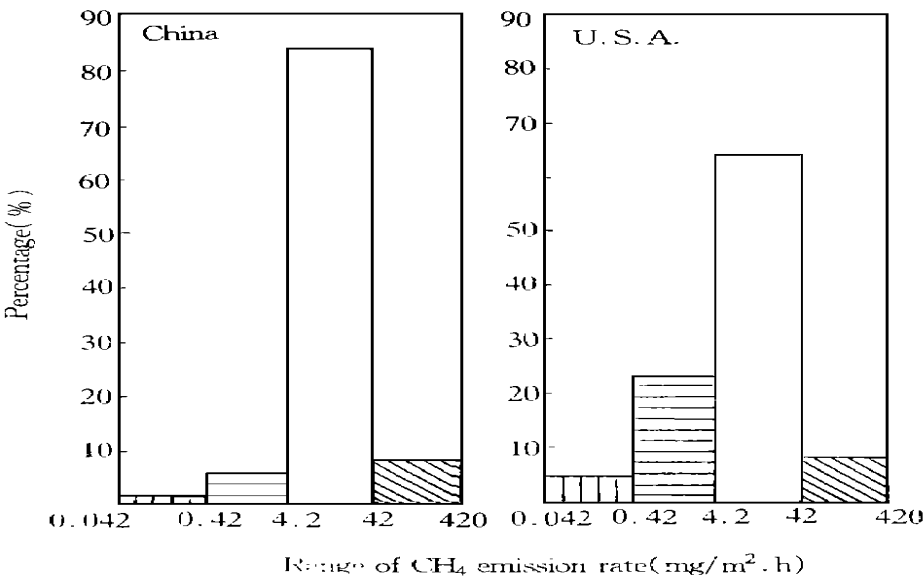


Fig. 5 The histogram of CH₄ emission from marshlands at the same latitude

tion range of CH₄ emission rate in the Sanjiang Plain is between 0.18 mg/(m²•h) and 14.38 mg/(m²•h) , while America’s is between 0.125 mg/(m²•h) and 80.96 mg/(m²•h), they have some relative consistency. So we can see that geographic position(mainly the latitude) has decisive effect while the difference of the vegetable types in marshlands is the main factor to lead to the difference of CH₄ emission rate.

V. ESTIMATION FOR METHANE EMISSION FROM MARSHLAND IN THE SANJIANG PLAIN

On the basis of all data obtained in 1995 and 1996 and the growing season from May to September, we calculate monthly CH₄ emission amount according to the average monthly emis-

sion rate, then calculate annual emission amount by accumulating the monthly amount. At the same time, we also take different marshland types and different CH₄ emission rate into account in estimation. The result shows: CH₄ emission amount in marshland is about 0.75 Tg every year in the Sanjiang Plain(Table 2).

Table 2 Estimation of methane emission from marshland in the Sanjiang Plain

Marshland type	Area (km ²)	1995		1996	
		CH ₄ emission	CH ₄ emission	CH ₄ emission	CH ₄ emission
		rate [mg / (m ² • h)]	amount (T g / a)	rate[mg / (m ² • h)]	amount(T g / a)
<i>Carex lasiocarpa</i>	4492.3	6.72 (May)		10.18 (May)	
		6.72 (June)		11.98 (June)	
		12.7 (July)	0.2567	24.80 (July)	0.2794
		28.7 (Aug.)		29.48 (Aug.)	
		22.9 (Sept.)		7.77 (Sept.)	
<i>Carex schmidtii</i>	2841.7	13.13	0.1370	13.13	0.1370
<i>Glyceris spiculosa</i> – <i>Carex</i>	2415.5	25.95	0.2302	25.95	0.2302
<i>Phragmites communis</i> – <i>Calamagrostis angustifolia</i>	591.7	28.92	0.0628	28.92	0.0628
Other marsh	850.7	15.81	0.0494	15.81	0.0494
Total	11192.9	/	0.7361	/	0.7588

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