Appendix A: Guidelines for Measuring Methane and Nitrous Oxide Emissions from Rice Paddy Fields

This appendix explains how the methane (CH_4) and nitrous oxide (N_2O) emissions can be measured in rice paddy fields. It is necessary that the implementation of CH_4 and N_2O measurement by a closed chamber method involves technicians who have been authorized by the independent experts before the validation and operators who have been trained by the authorized technician.

In order to obtain the independent experts' advice on the competence of the technicians or to propose alternative methods other than those explained in this appendix to be included in this methodology with sufficient scientific evidence, firstly project participants need to contact the Ministry of Agriculture, Forestry and Fisheries of Japan as a representative of the Expert Committee established under the initiative of the Asian Development Bank for Climate-Resilient Agriculture and Low-Carbon Food Systems in the ASEAN Region as follows: maff_JCMTML@maff.go.jp

The following tables are arranged sequentially from the chamber design to the calculation of the seasonal CH_4 and N_2O emissions and emission factors. See also "Guidelines for Measuring CH_4 and N_2O Emissions from Rice Paddies by a Manually Operated Closed Chamber Method" (pdf file, 8.4 MB) for the scientific basis and better understanding of the following guidance through the visual presentation.

Table A-1. Chamber design

Feature	Conditions
Material, color, and shape	In general, chamber shapes and materials are inseparable factors. In addition, chamber shapes allowed are dependent on a rice planting system. Cylinder-shaped chambers with round basal area are usually made of commercially available non-transparent plastic containers. Painting those with whitish color, if not inherent, or a cover with reflective material is recommended to prevent the increase in the inside temperature. Cylinder-shaped chambers can be used only for the direct broadcast seeding system. Rectangular-shaped chambers with square basal area are made of transparent acrylic plates (with stainless steel frames for the reinforcement, if necessary).

	Rectangular-shaped chambers can be used for both transplanting system and the direct seeding system (broadcast or row). The total chamber height (including that of a chamber base) is recommended to be higher than the rice plant height. Double- or triple-deck style is available to the rectangular-shaped chambers, which are adjustable depending on the growing plant height. The constant placement of chambers equipped with upper lids that can be opened and closed is not recommended.
Base material and shape	The chamber base needs to be installed at least one day before the first gas sampling and must remain in the field throughout the season. Base materials and shapes depend on the chamber shapes. The aboveground height of the bases is recommended to be lower than or equal to 30 cm. For cylinder-shaped chambers, a round-shaped base with a water sealing is usually made of plastic materials. A cylinder-shaped base in the soil requires holes on the sidewall to allow water exchange between inside and outside the chamber area. For rectangular-shaped chambers, 4 corner pillars, made of PVC pipes or metal rods, stuck into the plow pan are sufficient when there is surface water. Top of the pillars are required to be underwater for sealing. When there is no or shallow surface water, chambers can be gently placed on the soil. CH_4 ebullition may happen after the placement, and it should be escaped from or well mixed in the chamber headspace before the first gas sampling. Square-shaped bases with water sealings made of plastic materials are also available temporarily or constantly during the season.
Basal area	The total area covered by chambers in one field is required to be wider than 0.25 m^2. To accommodate this area, multiple ($n \geq 2$) chambers are used in one field. The minimum distance between each chamber should be 1 m. For the transplanting system, the basal area size of a rectangular-shaped chamber should be a multiple of rice plant spacing to appropriately capture GHG emissions (diffusion and ebullition) from the soil or the surface water. For example, if the plant spacing is 30 cm × 15 cm, the basal area should be 30 cm × 30 cm (covering 2 rice hills), 30 cm × 60 cm (4 hills), or etc. For the

	direct row seeding system, one side length of the basal area should be a multiple of the row distance.
Accessory	A chamber needs to be equipped with a gas sampling port, an inside fan, an inside thermometer, and an air vent. The port may also serve as the vent. The port should be apart from the chamber wall by using a tube connected to a stopcock. The dead volume in the tube should be replaced before the gas sampling. A weight, such as a battery for the fan operation, can be gently placed on the upper lid to prevent the chamber from falling down in windy weather.

Table A-2. Gas sampling

Feature	Conditions
Chamber area	A scaffold needs to be installed at least one day before the first gas sampling to reach the chamber areas without disturbing the soil. The chamber area needs to be apart 1.5 m from the ridge of the field.
Chamber replication per field	At least 2 chambers, depending on the basal area size (see the basal area feature in Table A-1).
Number of gas samples per chamber placement	At least 3 samples during the chamber closure time (30-40 min). The first gas sample should be collected after ≥1 min after the chamber placement to wait for the headspace gas to become well-mixed.
Gas sampling time of day	Morning, especially in the early hours (e.g., 7 am-10 am). If the sampling time must be extended to daytime, the schedule should be designed to prevent the systematic bias since CH_4 emissions are emitted more in daytime.
Frequency	At least once per week. To better trace the possible temporary CH_4 emission peak during a drainage event and the possible temporary N_2O emission peak after nitrogen fertilizer topdressing, additional measurements once or twice are recommended during these events.

Gas storage	The gas sampled from the port should be stored into a glass or plastic evacuated vial (with a rubber stopper), a plastic or aluminum bag, or a plastic syringe. A gas leak test for the expected storage duration needs to be implemented before the start of the season and the gas concentration analyzed needs to be corrected appropriately, if applicable.
Manual operation	Uniform and gentle manual operation needs to be implemented regardless of time and place. Several operators should simultaneously implement the measurement in the reference fields and project fields. When moving a chamber from one location to another, the air inside the chamber should be replaced by pushing the chamber sideways and operating the fan. It is necessary to submit a film recording a series of gas sampling operations by the technicians to the independent experts for authorization of their skill prior to validation. If the technicians' skills are insufficient, the film shall be resubmitted in accordance with the independent experts' advice.

Table A-3. Laboratory gas analysis

Feature	Conditions
Method	A CH_4 concentration needs to be analyzed by a gas chromatograph (GC) equipped with a flame ionization detector (FID) or a laser spectroscope. A N_2O concentration needs to be analyzed by a GC equipped with an electron capture detector (ECD) or a laser spectroscope. In case of using a laser spectroscope[1], project participants should follow the manufacture's instruction for the gas analysis.
GC system	A GC system consists of a gas injection port, a separation column, a gas detector, a data processor, etc. Carrier gas and the standard gas are essential for the steady operation and the analysis. An ECD-GC should be equipped with a multi-port valve to remove oxygen and water vapor for the refined detection of N_2O. It is necessary to submit the specification of GC system (product, column

[1] A portable laser spectroscope connected online to multiple chambers is to be usable if the method is scientifically sound and if all the requirements are met.

	packing material, column diagram, carrier gas and the flow rate, temperatures of injector, column, and detector) and photos of GC appearance (the entire GC from multiple angles (exterior) and columns inside the oven) to the independent experts before the validation.
Calibration line or curve	The certified standard gases need to be used to draw a calibration line or curve. 2-point calibration is sufficient for an FID-GC using the CH_4 standard gas with the atmospheric ambient concentration (e.g., ~2 ppm) and a higher concentration (e.g., 50-100 ppm). 2- or 3-point calibration is sufficient for an ECD-GC using the N_2O standard gas with the atmospheric ambient concentration (e.g., ~0.3 ppm) and higher concentrations (e.g., 2-10 ppm). Note that the linearity is not always secured for an ECD-GC to detect the higher concentration of N_2O. A calibration line or curve needs to be drawn each day before and after the analyses.
Quality control	The repeatability of the GC analysis needs to be tested before the start of the season using the certified standard gases. The coefficient of variation (CV) of 10-20 repeated analyses of the same standard gas should be ≤ 5% for all the used standard gases (i.e., ambient and higher concentrations). It is necessary to submit the results of the repeatability test to the independent experts for approval of quality control before the validation. If the results are poor (i.e., CV > 5%), the result of additional blind test is recommended to submit.

Table A-4. Calculation of the seasonal total emission of CH_4 or N_2O and emission factors

Order	Procedure
1	Calculate the mass of CH_4 or N_2O in the analyzed gas sample: $$m_t = c_t \times V \times M \times \frac{1atm}{R \times T_t \times 1000}$$ Where: m_t = Mass of CH_4 or N_2O in chamber at time *t* (mg) t = Time point of gas sampling (e.g. 1, 16, and 31 min after chamber placement in case of 3 samples for 30 min)

	c_t	=	CH_4 or N_2O concentration in chamber at time *t* (ppm)
	V	=	Chamber volume (L)
	M	=	Molar mass of CH_4 (16.042 g mol^{-1}) or N_2O (44.0128 g mol^{-1})
	$1atm$	=	Assume constant pressure of 1 atm, unless the inside pressure is recorded
	R	=	Universal gas constant: 0.08206 L atm K^{-1} mol^{-1}
	T_t	=	Temperature at time *t* (K)
2	Determine the slope of the line of best fit for the values of over time: $$s = \frac{\Delta m}{\Delta t}$$ Where:		
	s	=	Slope of line of best fit (mg min^{-1})
3	Calculate the hourly flux for one chamber measurement: $$F_{ch} = s \times \frac{60min}{A}$$ Where:		
	F_{ch}	=	Flux of chamber ch (mg m^{-2} h^{-1})
	ch	=	Index for replicated chamber in a field
	A	=	Chamber basal area (m^2)
4	Calculate the average hourly flux in a field: $$F = \frac{\sum_{ch=1}^{n} F_{ch}}{n}$$ Where:		
	F	=	Average flux of a field (mg m^{-2} h^{-1})
	n	=	Number of replicated chambers in a field
5	Calculate the total emission in one measurement interval: $$E_i = \frac{(F_i + F_{i+1}) \times 24h \times D_i}{2}$$ Where:		
	E_i	=	Total emission in interval *i* (mg m^{-2})
	i	=	Index for measurement interval in a season
	F_i	=	Hourly flux at the start of interval *i* (mg m^{-2} h^{-1})
	F_{i+1}	=	Hourly flux at the end of interval *i* (mg m^{-2} h^{-1})
	D_i	=	Number of days in interval *i* (d)
	Note that flux on planting day and flux on harvest day can be assumed to be zero if		

	measurement is not implemented on those days.
6	Calculate the seasonal total emission in a field: $E = \sum_{i=1}^{N} E_i$ Where: E = Total emission in a season (mg m^{-2}) N = Number of measurement intervals in a season
7	Calculate the emission factor in stratum *st* in season *s* $EF_{s,st} = \frac{\sum_{f=1}^{F} E_f \times 10^{-2}}{F}$ Where: $EF_{s,st}$ = Emission factor in stratum *st* in season *s* (kg ha^{-1} season^{-1}) E_f = Total emission in field *f* of stratum *st* in season *s* (mg m^{-2} season^{-1}) F = Number of (representative) fields of stratum *st* in season *s*
8	Calculate the emission factor per day in stratum *st* in season *s* $EF_{s,d,st} = \frac{\sum_{f=1}^{F}\left(\frac{E_f \times 10^{-2}}{D_f}\right)}{F}$ Where: $EF_{s,d,st}$ = Emission factor per day in stratum *st* in season *s* (kg ha^{-1} d^{-1}) E_f = Total emission in field *f* of stratum *st* in season *s* (mg m^{-2} season^{-1}) D_f = Total number of rice growing days in field *f* of stratum *st* in season *s* (d season^{-1}) F = Number of (representative) fields of stratum *st* in season *s*