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 a technician who has been approved by independent experts before the validation and operators trained by the technician.

In order to get the certification, project participants should contact the Ministry of Agriculture, Forestry and Fisheries of Japan as a representative of the Expert Committee 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. 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 |
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| 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 (transplanting or direct seeding).<br><br>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 seeding system.<br><br>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 |

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| | be used for both transplanting and the direct seeding system.<br><br>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.<br><br>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 no longer than 30 cm.<br><br>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.<br><br>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 |

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| | 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 density to appropriately capture GHG emissions (diffusion) from the soil or the surface water. For example, if the plant density 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. |
| 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 heavy battery for the fan operation should not be placed on the upper lid. |

Table A-2. Gas sampling

| Feature | Conditions |
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| 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 | 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. |

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| placement | |
| 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 spatial 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. After one measurement, the air inside the chamber should be replaced.<br><br>It is necessary to submit a film that records a series of gas sampling operations by operators trained by the technician to the independent experts to approve their skill before the validation. If the operator’s skill is insufficient, further training and resubmission of the film are required. |

Table A-3. Laboratory gas analysis

| Feature | Conditions |
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| 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 gas chromatograph (GC) equipped with an electron capture detector (ECD) or a laser spectroscope.<br><br>In case of using a laser spectroscope, project participants should follow the manufacture's instruction for the gas analysis. |
| GC system | The 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.<br><br>The ECD-GC should be equipped with a multi-port valve to remove oxygen and water vapor for the refined detection of $N_2O$.<br><br>It is necessary to submit the column diagram and photos of GC appearance with and without opening the oven door 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 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 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 ECD-GC to detect the higher concentration of $N_2O$.<br><br>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 |

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| | coefficient 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.<br><br>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 |
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| 1 | Calculate the mass of $CH_4$ or $N_2O$ in the analyzed gas sample:<br>$$m_t = c_t \times V \times M \times \frac{1atm}{R \times T_t \times 1000}$$<br>Where:<br>$m_t$ = Mass of $CH_4$ or $N_2O$ in chamber at time *t* (mg)<br>$t$ = Time point of gas sampling (e.g. 1, 16, and 31 min after chamber placement in case of 3 samples for 30 min)<br>$c_t$ = $CH_4$ or $N_2O$ concentration in chamber at time *t* (ppm)<br>$V$ = Chamber volume (L)<br>$M$ = Molar mass of $CH_4$ (16.042 g mol$^{-1}$) or $N_2O$ (44.0128 g mol$^{-1}$)<br>$1atm$ = Assume constant pressure of 1 atm, unless the inside pressure is recorded<br>$R$ = Universal gas constant: 0.08206 L atm K$^{-1}$ mol$^{-1}$<br>$T_t$ = Temperature at time *t* (K) |
| 2 | Determine the slope of the line of best fit for the values of over time:<br>$$s = \frac{\Delta m}{\Delta t}$$<br>Where:<br>$s$ = Slope of line of best fit (mg min$^{-1}$) |

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| 3 | Calculate the hourly flux for one chamber measurement:<br>$$F_{ch} = s \times \frac{60min}{A}$$<br>Where:<br>$F_{ch}$ = Flux of chamber ch (mg m$^{-2}$ h$^{-1}$)<br>$ch$ = Index for replicated chamber in a field<br>$A$ = Chamber basal area (m$^{2}$) |
| 4 | Calculate the average hourly flux in a field:<br>$$F = \frac{\sum_{ch=1}^{n} F_{ch}}{n}$$<br>Where:<br>$F$ = Average flux of a field (mg m$^{-2}$ h$^{-1}$)<br>$n$ = Number of replicated chambers in a field |
| 5 | Calculate the total emission in one measurement interval:<br>$$E_i = \frac{(F_i + F_{i+1}) \times 24h \times D_i}{2}$$<br>Where:<br>$E_i$ = Total emission in interval *i* (mg m$^{-2}$)<br>$i$ = Index for measurement interval in a season<br>$F_i$ = Hourly flux at the start of interval *i* (mg m$^{-2}$ h$^{-1}$)<br>$F_{i+1}$ = Hourly flux at the end of interval *i* (mg m$^{-2}$ h$^{-1}$)<br>$D_i$ = Number of days in interval *i* (d)<br>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:<br>$$E = \sum_{i=1}^{N} E_i$$<br>Where:<br>$E$ = Total emission in a season (mg m$^{-2}$)<br>$N$ = Number of measurement intervals in a season |
| 7 | Calculate the emission factor for the gas in stratum *st* in season *s*<br>$$EF_{s,st} = \frac{\sum_{f=1}^{F} E_f \times 10^{-2}}{F}$$ |

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| | Where:<br>$EF_{s,st}$ = Emission factor of the gas in stratum *st* in season *s* (kg ha$^{-1}$ season$^{-1}$)<br>$E_f$ = Total emissions of the gas in field *f* of stratum *st* in season *s* (mg m$^{-2}$ season$^{-1}$)<br>$F$ = Number of (representative) fields of stratum *st* in season *s* |
| 8 | Calculate the emission factor for the gas per day in stratum *st* in season *s*<br>$$EF_{s,d,st} = \frac{\sum_{f=1}^{F}\left(\frac{E_f \times 10^{-2}}{D_f}\right)}{F}$$<br>Where:<br>$EF_{s,d,st}$ = Emission factor of the gas per day in stratum *st* in season *s* (kg ha$^{-1}$ day$^{-1}$)<br>$E_f$ = Total emissions of the gas in field *f* of stratum *st* in season *s* (mg m$^{-2}$ season$^{-1}$)<br>$D_f$ = Total number of days in field *f* of stratum *st* in season *s* (days season$^{-1}$)<br>$F$ = Number of (representative) fields of stratum *st* in season *s* |