B-51 Study on the good practice for CH_4、N_2O inventories and the assessment of practicability for countermeasure to control the anthropogenic CH_4 and N_2O

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1. Introduction

The goal of this study, which was undertaken considering these points, is to establish more detailed more complete inventories by promoting the selection and development of reduction measure technologies for use as core technologies that can be widely applied and by quantifying and analytically evaluating their characteristics. And aware of the need to consider the developing countries of Asia that, as the homes of 60% of the world's people, have the potential capacity to generate massive quantities of CH_4 and N_2O, the study strengthens research on the possibility of spreading the use of CH_4 and N_2O core countermeasure technologies and on establishing more complete more precise inventories. The study will play an important role in helping construct the IPCC inventory by studying and evaluating core CH_4 and N_2O reduction measure technologies now under development in various fields and the optimum methods of managing and operating these technologies, by strengthening measures to promote their wide use not only in Japan, but throughout the developing countries of Asia, and by evaluating the cost-benefits of their introduction.

2. Research Objectives

This study considered the refinement of inventories of anthropogenic sources of CH_4 and N_2O, which are beset with uncertainty, and the essential requirements for measures for establishing and spreading technologies required in individual fields, by including the perspectives of developing countries in Asia, which account for 60% of the world population and where a continuous rapid increase in population is anticipated. Study objectives in individual fields were as follows.

In the field of combustion and fuel spills, the objective was to develop catalysts for reducing N_2O emissions from fixed sources and improve precision in the inventories of N_2O from fixed sources and CH_4 emissions related to fuel spills. In the field of automobiles, the objective was to evaluate N_2O emissions in various countries using the same technique and

defines the precision of N_2O estimates. To that end, the precision of estimating N_2O emissions was improved by identifying correlations of N_2O emissions with driving modes that vary from country to country, and the practical usefulness of technologies to reduce N_2O emissions was evaluated. In the field of household and industrial wastewater treatment, the objectives were to improve precision in estimating CH_4 and N_2O emissions from bio-ecoengineering treatment of household and industrial wastewater and to establish core control technologies intended for dissemination at home and abroad through demonstration, and to develop simplified technologies that would be applicable to developing countries by taking into account utilization of the EFF system. In the field of waste, the objectives were to improve precision in estimating CH_4 emissions from final disposal sites and CH_4 and N_2O emissions from organic waste recycling and industrial waste treatment/disposal processes, and to establish core technologies to reduce emissions from final disposal sites. In the field of sewerage systems, the objectives were to establish CH_4 and N_2O emission coefficients suitable for advanced treatment for nitrogen and phosphorus control and advanced treatment of sludge, to improve precision of estimates, and to evaluate the reduction method of introducing organic waste such as garbage into local sewerage facilities for CH_4 fermentation and utilization of generated CH_4. In the field of agricultural and forest land, the objectives were to identify the amount of CH_4 and N_2O emissions and absorption involved in paddy and upland fields, forest soil, grassland and burning of agricultural residue in Asia, and to develop N_2O reduction technologies suitable for local agricultural fields. In the field of animal husbandry, the objectives were to develop a simplified technology to determine CH_4 emissions derived from animal husbandry in Asia, to improve precision in estimating CH_4 emissions from humped cattle and water buffalos, which are raised in great numbers in that region, to develop acceptable technologies to reduce CH_4 emissions in Southeast Asia, which is considered to have high CH_4 emissions, and to improve precision in estimating CH_4 and N_2O emissions from animal waste treatment.

To integrate and evaluate the studies in these fields, the focus was on CH_4 and N_2O inventories, which were important for evaluating the reduction performance of technologies developed and demonstrated in the research projects, and on the factors important for the effective spread of control technologies, such as cost, efficiency and flexibility, and comprehensive evaluation of emission control technologies was performed with respect to cost and environmental impacts to determine the possibility of refinement of CH_4 and N_2O inventories and of the realization and spread of individual measures.

As shown in the above, it can say that the characteristics of this research project are covered most anthropogenic CH_4 and N_2O sources. The scheme and the concept of this research project that it made use of these characteristics is shown at Fig.1.

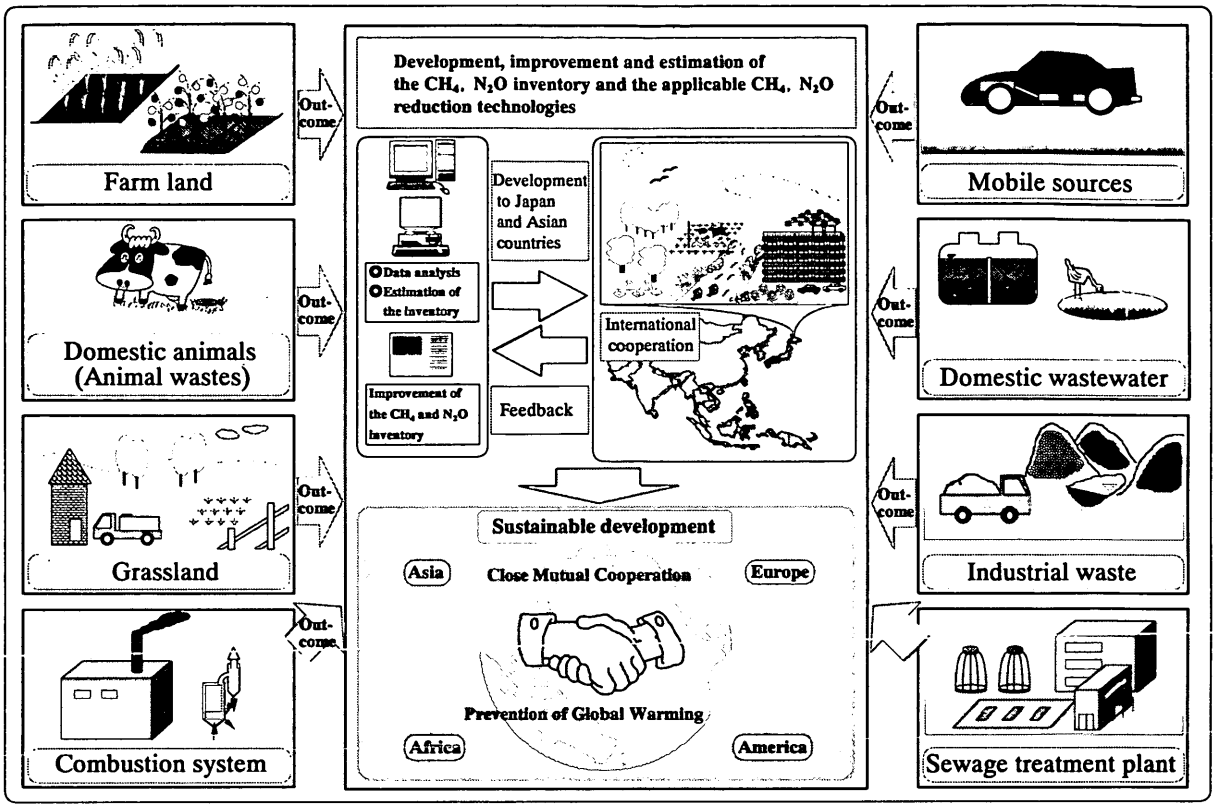

Fig.1 The scheme and the concept of the research project

3. Results

3.1 Combustion and Industrial Activity

The catalytic decomposition of N_2O was studied over Rh loaded metal oxides. The Rh loaded on ZrO_2, Al_2O_3 showed rather high activity even in the presence of water and NO_2. Furthermore, for Fe-zeolite catalyst that has been reported as very active catalyst for N_2O decomposition in the presence of SO_2 and H_2O, the effect of support material and supporting method of Fe over the zeolite on the activity of N_2O decomposition and reduction was investigated. The highest activity was obtained when $FeCl_2$ was used as the starting material for Fe and was loaded over ferrierite by solid ion exchange method. Fe-BEA showed high activity in the reduction of N_2O by CH_4. In the selective reduction of NOx with ethanol over Ag/Al_2O_3, the conversion to N_2O was large and NH_3, HCN and CH_3CN were also produced at low temperatures. High concentration of N_2O and NOx were produced when those nitrogen-containing by-products were treated on Pt/TiO_2. A composite catalyst of Ag +Cu +Pt gave higher NOx reduction and lower N_2O production than Ag/Al_2O_3. It was found that NOx could be reduced to N_2 very effectively by methanol over ferrierite-supported catalysts without producing large amount of N_2O. Continuous monitoring of N_2O was done for 6 fluidized bed sewage sludge incinerators in 7－14 days. N_2O emission varied largely with operation conditions of incinerator. These results suggest that determination of N_2O emission factor by grab sampling or short-term measurement may have low certainty. Emission factors between 350 － 1416 g-N_2O·t-wet sludge^{-1} were obtained. N_2O emission from 17 units was estimated by using a correlation of N_2O emission

and freeboard temperature. Average N_2O emission factor was estimated as 733 g-N_2O·t-wet sludge^{-1}. To obtain CH_4 emission by coal exploitation in Japan, the emission by open-pit and underground coal mine operations were investigated. Field monitoring of CH_4 flux from open-pit coal mine was not succeeded because of the CH_4 concentration was much lower than the estimation. CH_4 emission from underground coalmines was investigated and the relationship between the depths of working faces and released CH_4 quantity per coal production was obtained. CH_4 emission in Japan is relatively larger than foreign countries' results reported in papers.

3.2 Automobile

Variation in estimates of the total quantity of N_2O emissions from automobiles among researchers even in the base level has been always under question. It is thought that the wide variation in estimates is attributed primarily by the test driving modes, types of catalysts mounted on the test vehicles, different levels of catalyst deterioration, and the ambient temperature.

From such a viewpoint, it is found in the quantitative analysis that the increase in the lifetime of vehicle is a phenomenological cause of increase in the base level of N_2O emission. Therefore considering the increasing rate of N_2O emission as the weight factors, it is possible to estimate the gross mass emission of N_2O from a vehicle more accurately. Moreover, to improve accuracy of estimating the annual gross N_2O mass emission, it is necessary to consider the compensations for ambient temperature of respective seasons. N_2O emission behavior in the real road condition is also observed using an exhaust gas flow meter developed in this study. It is found that especially during this restart period the mass emission of N_2O is extremely high. Therefore, in order to have highly accurate gross estimation of N_2O emission, it is essential to adopt a new N_2O emission measurement mode.

3.3 Agricultural Field and Forest Field

A series of studies is conducted to evaluate CH_4 and N_2O emissions from cultivated land in Asia. The studies include field experiments and measurements in various agro-ecosystems in Japan and China, combustion experiments of biomass in India, and scaling-up of the observation. The factors of direct N_2O emissions relative to the nitrogen application rates are determined in several important agricultural sources. The factor in an onion field in Hokkaido ranged 2.7-7.8%. Whereas, those in grassland in Hokkaido and upland field in Jiangxi province, China, ranged 0.05-0.23% and 0.13-0.40%, respectively. That in Japanese greenhouse tomato cultivation on yellow soil was lower than 0.1%. Process studies revealed vertical distribution of microbial activity for N_2O production in soil between surface and 100 cm depth after fertilizer application. Soil incubation experiments indicated inhibition of CH_4 oxidation and absorption by the addition of ammonium nitrogen. Field measurements showed the trade-off between CH_4 and N_2O emissions from grassland and wetland in eastern Hokkaido, Japan, and northeastern parts of China. Different methods to scaling-up the observation were tested. A process-based model, DNDC model, was

validated by Japanese field data. The model properly simulated N_2O emissions from Japanese Andisol fields by integrating the parameters for the ratio of microbial biomass carbon to total carbon in the soil. The empirical method to compile the inventories of N_2O emissions and agricultural statistics estimated annual emission rate of N_2O from Japanese cultivated land to be 7.89 Gg N in 1998. Mitigation options for CH_4 emission from paddy fields are examined. Drainage of the fields in winter fallow period significantly mitigated CH_4 emission from a paddy field in southwestern China. While, the mitigation effect of no-till treatment in paddy fields at Okayama, Japan, was cancelled after continuing the treatment for several years. Combustion experiment of biomass in India suggested that emission factors for many trace gases were larger than those in IPCC reports.

The CH_4 and N_2O fluxes from Japanese forest soils were measured at 27 experimental sites from Hokkaido to Okinawa. The averaged CH_4 uptake rate in no snow seasons ranged from 0.14 – 5.15 $mg\text{-}C \cdot m^{-2} \cdot d^{-1}$. The averaged CH_4 uptake rate in Hokkaido was 1.57 ± 0.85 $mg\text{-}C \cdot m^{-2} \cdot d^{-1}$, which was relatively smaller than that of the area southward to Hokkaido (2.13 ± 1.21 $mg\text{-}C \cdot m^{-2} \cdot d^{-1}$). The averaged CH_4 fluxes in different ecosystems had high correlation with the CH_4 uptake potential of 5cm topsoil. The CH_4 uptake rate was inhibited by water-soluble Aluminum solution (1 – 5 mM), this result suggesting that water-soluble Aluminum is one of the important regulating factors of CH_4 uptake rate of soils. The soil on forest burned had high water-soluble Aluminum, which could suppress the CH_4 uptake rate. The N_2O flux increased with the increase of soil temperature. The N_2O flux in each watershed had wide variation ranged from 0.03 – 0.8 $kg\text{-}N \cdot ha^{-1} \cdot y^{-1}$. The higher the N_2O fluxes were, the higher the nitrate contents in the soil were. The nitrate concentration in the stream had high correlation with N_2O flux. This result suggests that the nitrate concentration in the stream is good indicator of N_2O flux. According to the relationship between the nitrate concentration in the stream and N_2O flux, it is estimated that 3.1 % of nitrate eluted by nitrate saturation disappear by N_2O.

3.4 Stock Raising

In order to improve the accuracy of inventory of CH_4 and N_2O emission from the animal production system, the SF6 tracer method that should be possible to measure the CH4 production from ruminant had been developed. This method showed good correlation against the chamber method and measurement in the large area was made possible. Using this method the CH_4 conversion rate from Buffalo calves is estimated 10 to 12 % of gross energy intake and is affected by feed quality, and the CH_4 emission from buffalo in Indonesia is estimated to be 166 $Gg \cdot year^{-1}$, which is approximately 3.5% of total CH_4 emission in Indonesia.

It is related wastewater treatment, the CH_4 emission during wastewater treatment was estimated 0.2 – 0.05% of total organic carbon in wastewater and the N_2O emission was approximately 5% of the influent nitrogen for the conventional method, but the N_2O emission could be reduce less than 0.05 % of the influent nitrogen by using the intermittent aeration process. The CH_4 and N_2O emissions from the pig breeding unit and its manure

contributes (a full fattening period of 8 weeks) were estimated at 270－438 g-CH_4·$head^{-1}$ and 16.5－49.7 gN_2O-N·$head^{-1}$, respectively. Those emission could be reduced by adequate manure contributes, such as; weekly discharge of slurry in pig unit, employment of intermittent aeration process for wastewater treatment and keeping of aerobic condition during pig manure composting with adequate aeration. The N_2O emission from livestock waste composting was lower for forced aeration type (approximately 0.5% of the influent nitrogen) than for the conventional type (3.9－5.9% of the influent nitrogen). On the other hand, the CH_4 emission was also lower for forced aeration type (high aeration rate (77 L·m^{-3}·min^{-1}): 0.001% of total organic carbon) than for conventional composting type (0.24－0.28% of total organic carbon).

To develop nutritional management for controlling CH_4 emissions from Southeast Asian ruminants, the influence which nutritive value of tropical grass exerted on CH_4 emission from cattle was examined. As that results, four Holstein cattle were fed Bahia grass hay, Guinea grass hay and two kinds of corn silage to measure amount of CH_4 formation. Guinea grass and one corn were new varieties with high digestibility. TDN contents in new varieties were high, and the amount of CH_4 formation decreased to 70－93%.

It is related the influence of feeding broken rice for milk production and CH_4 emission from cattle, the milk production, milk element, and dry matter intake showed an increasing tendency when broken rice were fed. Also, cattle CH_4 emission decreased by adding broken rice from the 35.3 to the 29.5L per dry matter intake. The influence of the chemical treatment to rice straw affects the amount of CH_4 formation from cattle was that digestibility of rice straw was improved by adding 3% of urea and 0.0035% of cellulose. Also, cattle CH_4 emission decreased by chemical treatment from 73.1 to 55.7L per TDN intake. From above results, it was considered effective to control cattle CH_4 emissions in Southeast Asia by nutritional management - using new variety with high digestibility, adding broken rice and using chemical treatment to roughage.

3.5 Solid Waste Management

In order to obtain more precise estimation on CH_4 emission from waste landfill sites, its emission potential was estimated by analyzing industrial waste stream and the field monitoring technique for CH_4 emission from landfill surface was also developed. Paper waste, wood waste, animal and plant residues, and organic sludge were considered to be major organic wastes. Transformation of amount and carbon content in these waste items were analyzed along their waste streams. It is important for precise estimation that waste streams through certain treatments, such as dehydration, must be included. The CH_4 emission from land filled organic sludge, which have not been estimated in the Japanese Communication yet, will be add a 60% of emission to present estimates from landfill. Further fractionation of waste streams by industries at generation would not always improve the precision of estimates. These results mean that considerations on quality and quantity change through waste streams were essential for reducing uncertainty of emission estimates

in this sector. In order to reducing cost, labor and time for monitoring of surface CH_4 emission, images obtained from an infrared thermal video camera was applied to screen hotspots at the landfill surface since landfill gas flux in waste landfill site would be also the thermal flux from waste layer. Amongst of over 100 hotspots, more than 90% of points showed significant CH_4 fluxes. On the other hand, reference points, which were randomly investigated, only 30% of points showed the significant CH_4 flux. Certain correlations of CH_4 flux with ground temperature were also confirmed. Using this relationship, whole CH_4 emission can be estimated from the distribution of ground temperature. This series of procedure is novel, simple and precise method for monitoring of surface CH_4 emission at landfill site.

3.6 Wastewater Treatment

Noting that CH_4 and N_2O emissions in this field result from microbial reactions, findings on the behavior of useful microorganisms in wastewater treatment systems were accumulated, the refinement of the treatment process by the introduction of these useful microorganisms and its effect on CH_4 and N_2O reduction were considered, and a demonstration study of the effect on CH_4 and N_2O reduction was conducted using an actual combined-type sewage treatment system. In addition, industrial wastewater treatment systems and eco-engineering wastewater treatment systems were evaluated for wastewater treatment characteristics, CH_4 and N_2O generation characteristics and reduction methods. Results indicate that the *nosZ* gene in household wastewater treatment sludge forms different clusters from the *nosZ* gene in other environments, suggesting the presence of microorganisms expressing *nosZ* mRNA even under slightly aerobic conditions. Results also indicated that the introduction of a useful nitrifying/denitrifying bacteria, *Alcaligenes faecalis*, into the household wastewater treatment process as a comprehensive immobilization carrier was quite effective in preventing reduction in nitrification/nitrogen removal capacity and reducing N_2O emissions, especially at low water temperature. In addition, in a demonstrative study of the effect of circulation of nitrified liquor in a wastewater treatment tank, the N_2O emission rate was almost the same for both circulation and non-circulation types, but the CH_4 emission rate was far higher for the non-circulation type than for the circulation type. These results show that the circulation of nitrified liquor in biological treatment is effective as a means of emission reduction in light of preventing eutrophication and reducing greenhouse gas emissions.

Salt contents have significant effects, especially on N_2O generation from the nitrification process, in biological removal of nitrogen from industrial wastewater. An increase in salt content had direct and indirect effects on N_2O generation in continuous operation using the anaerobic/aerobic circulation activated sludge process, suggesting the possibility of an occasional rapid increase in N_2O generation.

Findings were collected on emissions from soil trenches, constructed wetlands and lagoon systems, which are eco-engineering type wastewater treatment systems widely used in developing countries in Asia although the actual status of CH_4 and N_2O emissions from

them had been unknown, including observations in China and Thailand, in order to refine inventories. For the soil trench system, which has a great emission coefficient but is expected to show rapid spread, a simplified emission reduction method characterized by slight aeration into soil was developed.

In order to clear the detail CH_4, N_2O emission mechanism from the constructed wetland, a detailed examination was done to two typical systems, subsurface constructed wetland (SF) and free water surface constructed wetland (FWS). The results showed that SF showed more preferable pollutants removal performance and higher stability for wastewater treatment than FWS wetland. Based on measurement of ORP and vertical CH_4 and N_2O concentration, anaerobic zones inside wetlands were found to be responsible for the generation of CH_4 and both FWS and SF wetland showed same relationship with the redox potential of soil. The dry soil layer on the upper side of the water surface plays important role for the reduction of CH_4 in SF wetland and result in low emission of CH_4 in it. According to the results about nitrification activity distribution in wetland, root zones were proven to be important parts for nitrification both in FWS and SF wetland. Nitrification process was proven to be one important reason of N_2O emission in FWS wetland and was proven not to be significantly responsible for N_2O emission in SF wetland. In another word, the structure of FWS wetland makes the ORP distribution preferable for the generation of CH_4 and N_2O than SF wetland. At the same time, the distribution of water-contained gas and the methanotrophic bacteria showed that the structure of SF wetland make the distribution of methanotrophic bacteria to be more favorable for CH_4 reduction.

Though the kind of plants and BOD loading are important as one more point of view for this system Purification potential of *P.australis* and *Z.latifolia* plant during wastewater treatment of different pollutant load were almost at the same level. CH_4 flux was consistently higher from *Z.latifolia* unit than from *P.australis* unit. The higher biomass of methanogens in the *Zizania* unit than *Phragmites* unit may be the reason for the higher CH_4 emission from the *Zizania* wetland unit. The root of *Z. latifolia* is shallow and the activity of methaothrophs is mainly confined in upper portion of the soil but the root of *P. australis* is deeper and can oxidize CH_4 up to more depth. It was thought that this favorable structure is good for reducing CH_4 emission from wetland.

These studies indicated the compatibility between eutrophication measures and greenhouse gas emission reduction measures in wastewater treatment systems using bio-ecosystems, and useful findings were accumulated on emission coefficients for CH_4 and N_2O from ecoengineering treatment systems, which had been studied quite inadequately.

On the other hand, with municipal sewage system, the recycled nitrification/denitrification process was high with effect of decrease anaerobic-oxic activated sludge process and conventional activated sludge process were the same control effect almost. There was much N_2O emission quantity when imperfect nitrification process in the time when treatment to bad time and nitrification promotion. For the sludge treatment process, the incineration is the most dominant process for N_2O emission. Here, it was cleared that the N_2O emission amounts are strongly influenced for the free board

temperature and it is easy to estimated from the temperature. The N_2O gross weight from the fluidized bed furnace of Japan was 3.6Gg-$N_2O \cdot year^{-1}$.

3.7 Overall Evaluation for Countermeasure to control anthropogenic CH_4 and N_2O

Using the CH_4 and N_2O emission reduction technologies studied in this research project as a model case, the cost-effectiveness of greenhouse gas reduction measures and reduction potential were estimated, and methods for overall evaluation of the possibility of applying control measures, including indirect effects, were developed. Results from the study of cost-effectiveness in individual control technologies showed that an improvement in feeding technologies in animal husbandry would result in an increase in income. "Change in the combustion method of sludge" and "change in basal fertilizer" were shown to result in a reduction rate of 200-300 g-$CO_2 \cdot yen^{-1}$, and "blowing auxiliary fuel gas into combustion equipment" and "change in household wastewater treatment" were shown to result in a reduction rate of less than 10 g-$CO_2 \cdot yen^{-1}$. Regarding reduction potential in Japan, "improvement in the productivity of dairy cattle," "improvement in the productivity of fattening cattle," "improvement in automobile catalytic converters" and "change in the combustion method of sludge" were found to attain more than 1,000 Gg-CO_2. Methods for overall evaluation of control technologies from the perspectives of practicality and applicability were developed, and the methods took into account ripple effects, which were difficult to quantify.

Evaluation phases were divided into a phase in which the characteristics inherent in individual technologies were evaluated and another phase in which the characteristics of receiving regions were evaluated. In the former, common evaluation items such as "implementation requirements," "global warming," "effects on businesses," "environmental impacts" and "socioeconomic impacts" were rated by points on a scale of 3 to 5. In the latter, evaluation items were established in fields corresponding to those of the former and local issues were rated by points according to importance, in order for them to be weighted in the evaluation of emission control technologies in regions. In the overall evaluation including effects other than global warming, the items from the principal component analysis of official statistics, "global warming," "urban environment," "agricultural environment" and "economy and society," were rated by points according to importance in 86 countries. The Schematic diagram and flow of this evaluation method is shown at Fig.2.

Overall evaluation was performed using the ratings by points in Japan and China, and the results showed that improvements in infrastructure and the environment such as "change in household wastewater treatment" were highly rated in both countries, indicating the possibility of performing overall evaluation of factors including those other than global warming, reflecting regional characteristics, which had been difficult to evaluate from cost-effectiveness alone, by introducing "rating by points and weighting."

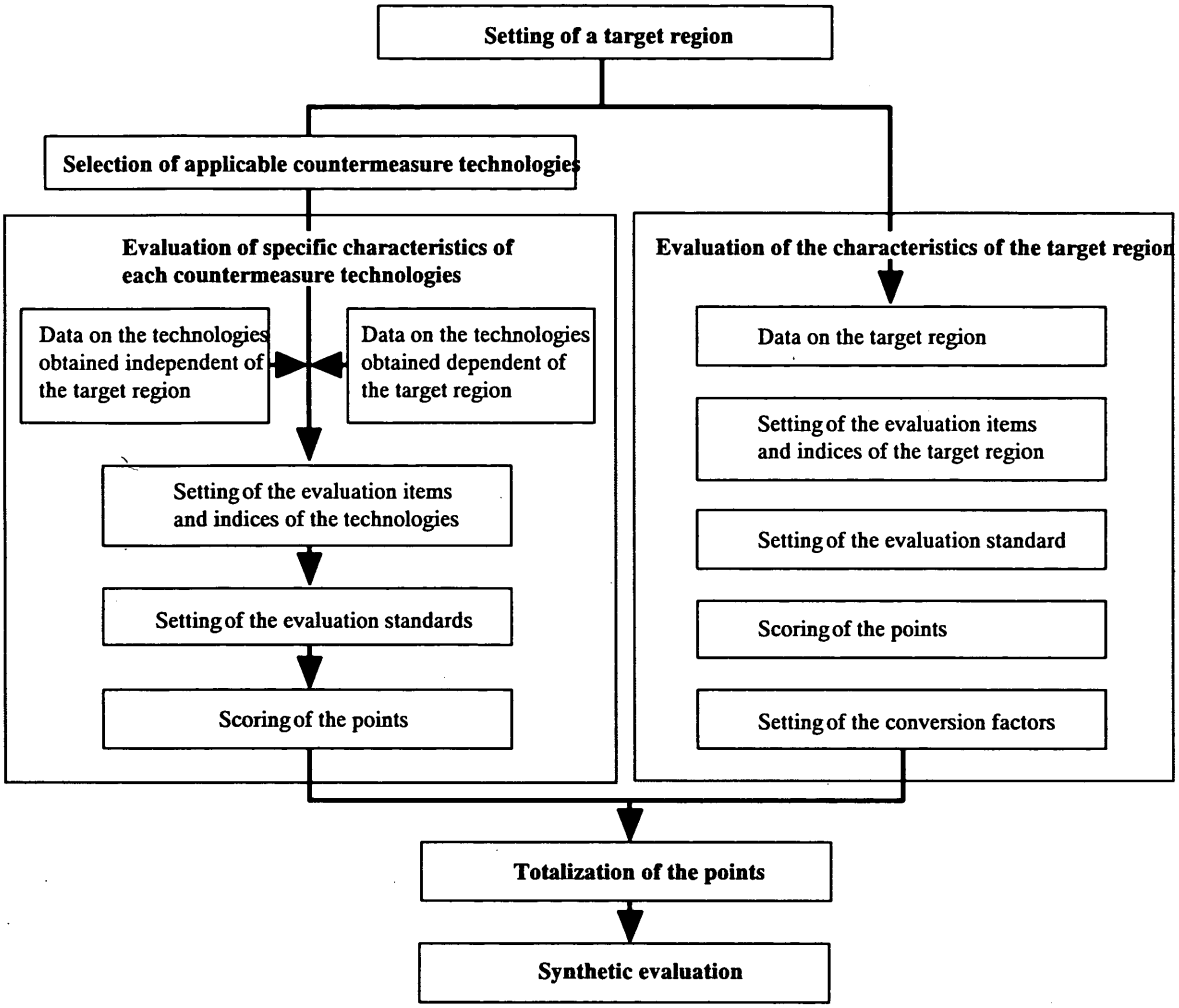

Fig.2 Evaluation flow of the measure technologies

To perform evaluation of the uncertainty of emission coefficients for individual emission sources in order to refine and expand inventories, a system was considered to evaluate how much the project helped to reduce uncertainty in estimating emissions by introducing the results of individual subjects of the project based on the uncertainty evaluation method described in IPCC Good Practice Guidance. Because the uncertainty in emission estimation has tended to be underestimated, a direct comparison of past uncertainty evaluation results with the latest evaluation results may result in increased uncertainty due to progress in research. Thus, a decision was made to reevaluate the uncertainty involved in past emission estimates, based on the latest knowledge, and then evaluate the effects of research results on the reduction in uncertainty. As a result, relative evaluation of uncertainty was made possible. A finding during the development of this method was that if the current IPCC uncertainty evaluation was used, there would be confusion between the uncertainty that would be reduced by progress in research (such as measurement errors) and the uncertainty that would not (in the case of great variance in actual distribution), suggesting a need to examine the type of uncertainty.

4. Conclusion

This study aimed for the refinement of inventories of anthropogenic sources of CH_4 and N_2O, which had been beset with uncertainty, and the development of emission control technologies, and aimed to examine evaluation methods, by including the perspectives of developing countries in Asia.

Regarding inventory refinement, study results clarified the detailed characteristics of emissions from sludge incinerators, fixed combustion equipment with high emission coefficients, and mines and the effects of environmental factors on automobile emissions, which had caused great errors in emission coefficients. In the agricultural field, the coefficients for emissions from paddies and upland fields were investigated in Japan and other Asian countries, and the thus far unknown coefficients for emissions from forest soil were estimated based on observations at 30 monitoring points in Japan. Regarding the estimate of emissions from animal husbandry, a simplified method for on-site measurement was developed and has allowed the estimate of emissions from water buffalos, which account for a large part in Asia. In the field of waste disposal, an accurate method for estimating emissions from landfills from landfill records was established and has allowed the precise determination of emission coefficients in accordance with wastewater treatment methods. In particular, findings were accumulated on the emissions from ecoengineering wastewater treatment systems, for which default values had not been specified in the IPCC guideline in spite of their popularity in developing countries in Asia, and inventories have been made available for most of the anthropogenic emission sources. Regarding emission control measures, the performance of catalysts used for fixed combustion equipment and automobiles was evaluated, and catalytic converters for exhaust gas currently being introduced have especially been found effective for N_2O reduction and are expected to spread and thereby remarkably reduce emissions from automobiles. In the agricultural field, a dairy cattle rising in Southeast Asia, in particular, was noted and changing locally available feed developed an emission reduction method. In the field of waste disposal, the CH_4 reducing effect of cover soil on landfills was highly evaluated. In addition, eutrophication measures were found to be compatible with emission reduction measures in terms of operation conditions of wastewater treatment, and tree planting was found to play an important role in the ecoengineering approach.

This study placed an emphasis on the overall evaluation of emission control measures considered in the project and new inventories. First, a cost-effectiveness involving production goal was determined for emission control measures in individual fields, and then reduction potential in Japan was made clear. As a result, some emission control measures applied were found to result in an increase in production. To evaluate the effects of application of these measures on evaluation from a wide range of aspects including effects on original purposes and ripple effects, as well as effects on reduction potential, an overall evaluation method was developed that involved extracting related evaluation items, establishing criteria for individual items, rating them by points, and combining weighting for regional economic conditions. These allowed the quantification of indicators used for

the application of emission control technologies at home and abroad, including not only the amount and cost of CH_4 and N_2O reduction but the socioeconomic impacts of technological application, while considering the characteristics of these control technologies and receiving regions.

These studies ensured the objectiveness and practicability of the evaluation approach using rating by points, and this approach was expected to provide a useful support tool for prioritization of emission control technologies. Regarding evaluation of inventories of emission sources, a system was developed to evaluate how much the uncertainty in estimating emissions was reduced based on the uncertainty evaluation method described in IPCC Good Practice Guidance. Evaluation was made to determine the effectiveness of findings on emissions based on these results in reducing the uncertainty of inventories prepared based on these findings, and results showed that there would be confusion between the uncertainty that would be reduced by progress in research (such as measurement errors) and the uncertainty that would not (in the case of great variance in actual distribution), suggesting a need to examine the type of uncertainty.

As described above, this 3-year project seems to have attained the initial goals of preparing precise inventories of CH_4 and N_2O emissions from anthropogenic sources and proposing practicable emission control measures by taking into consideration the situation in Asia.