Characterize Additional and Uncertain N_2O Emission Sources

I. Objective

Nitrous oxide (N_2O) is the third most important greenhouse gas in California in terms of its contribution to the total global warming impact. It is important to accurately quantify N_2O emissions due to the large global warming potential and long lifetime of this pollutant. The bulk of N_2O emissions in California are produced through biogenic processes with large uncertainties due to variability of environmental conditions and the dispersed nature of emission sources. The objectives of this project are to 1) verify the current California Greenhouse Gas (GHG) inventory including identifying sources not yet accounted for; 2) improve the inventory accuracy through field measurements to provide updated activity and emission factors; and 3) identify potential mitigation measures to reduce N_2O emissions. The proposed study will provide a better understanding of N_2O emission sources in California, improve California's N_2O inventory, and assist California to reach its AB 32 goal to curb GHG emissions.

II. Background

Nitrous oxide is a potent GHG with a global warming potential of 298, compared to CO_2. N_2O can be emitted from many sources containing nitrogen (N). Both top-down and bottom-up methodologies have been used to estimate N_2O emissions. Individually, each approach has significant strengths and weaknesses, but used in concert can help verify the accuracy of emissions estimates. The current California N_2O inventory was developed using "bottom-up" approach based on statewide activities data and default emission factors (EFs) that were derived from state, national or international emission data. However, there are potentially unaccounted and uncertain N_2O sources from the California inventory due to lack of accurate EFs or activities data. Since 2009, ARB has funded several studies assessing N_2O emissions from nitrogen fertilizer use in agricultural land, a leading source of N_2O in the state, to reduce the uncertainty of the N_2O inventory. Investigation on other important sources such as mobile is also underway. This project will target additional potential sources of N_2O that have high uncertainty or have no methods of estimation. These sources may include landfills, wastewater treatment and discharge, ocean upwelling, plant nurseries, golf courses, water bodies subject to fertilizer runoff, etc.

In California, about 32 percent of the estimated 35 million tons of waste disposed in the landfills annually is compostable organic materials containing significant amount of N. Although N_2O emissions are expected from these landfills, N_2O monitoring data in California landfills are scarce. The current California inventory calculates N_2O emissions only from burned landfill gas as a ratio to methane (CH_4) emissions. Fugitive emissions of N_2O are not included. Several field studies indicate that N_2O emissions vary greatly among different landfills (Rinne et al., 2005; Zhang et al., 2009; Bogner et al., 2011; Zhang et al., 2013; Harborth et al., 2013). Many characteristics of landfills, such as properties of landfill cover, waste type, composition, and age, and in-situ environmental conditions can all affect the formation of fugitive N_2O as well as the emission ratio of N_2O to CH_4. Preliminary studies taken by ARB staff have detected spikes of N_2O from landfills that contain disposed green wastes. Strong N_2O hot spots of up to 24 ppmv (75 times that of background N_2O) from freshly landfilled wastes were also reported by Harborth et al. (2013).

Another uncertain N_2O source in California is the wastewater treatment system. The wastewater streams generated from homes and industrial and commercial facilities are rich in N, and therefore can produce significant N_2O during their transport, treatment and final disposal stages, in forms of both the treated effluent and sewage sludge (Czepiel et al., 1995; Kampschreur et al., 2009; Foley et al., 2010; Ahn et al., 2010; Law et al., 2012). The emission estimates of N_2O from California's wastewater treatment systems are based on U.S. Environmental Protection Agency (U.S. EPA)'s default EFs, accounting for emissions in both wastewater treatment plants and effluent discharge into surface water. The emissions from sewage sludge, or biosolids, produced from the wastewater treatment process are reported in composting and landfills sectors of the inventory. Besides the great uncertainties in the EFs which would vary with wastewater sources, composition, and treatment and control technology, N_2O emissions from sewage sludge is a potential source given its expected high residual N content. Another study suggests that N_2O emissions from the land applied sewage sludge account for more than 80 percent of GHG emissions associated with the wastewater treatment processes (Johansson et al., 2008).

Urban landscapes such as golf courses across the state, where high fertilizer use and irrigation depth are especially conducive to N_2O production, may be an additional source of N_2O emissions. Studies by Townsend-Small et al. (2011) in southern California indicate that urban landscapes such as lawns in parks and residential turfs can contribute a significant portion of the total N_2O emissions at regional scales. Development of emission factors from field measurements of N_2O emissions from urban landscape and better data on urban fertilizer use can help to improve the California N_2O inventory.

In order to characterize the full spectrum of N_2O emissions from the above sources, it is necessary to conduct field measurements to capture the spatial and temporal variability of the emission fluxes. N_2O emissions from the listed sources are known to occur from nitrification and denitrification processes, which are carried out by microbial activities and are highly sensitive to environmental factors, leading to extremely variable N_2O fluxes in response to site-specific conditions. Limited field studies and ARB's in-house research efforts have proven these additional N_2O sources, but data are not sufficient to allow for the development of emission estimates or emission factors. The proposed study is intended to provide that data so that such estimates can be obtained or improved.

III. Scope of Work

Due to limited resources, it is suggested that the project focus on landfills, wastewater treatment systems, and urban landscapes, especially golf courses, as the priorities in this research. The contractor may propose and investigate other potential sources if deemed significant. The project should include, at a minimum, the following tasks, which may be accomplished through collaboration with other State agencies such as Department of

Resources Recycling and Recovery (CalRecycle), State Water Resources Control Board (SWRCB), and California Department of Food and Agriculture (CDFA):

- Identify monitoring sites of landfills, wastewater treatment systems, and urban landscapes in California. The selection of the monitoring sites should consider both representativeness and expected emission fluxes. For landfills, the selection should focus on non-hazardous sites that receive compostable organic wastes, especially those that use green waste or biosolids as alternative daily cover. For wastewater treatment systems, factors to be considered should include the type of wastes received (residential, commercial and/or industrial), wastewater treatment technologies (primary and secondary treatment processes), sewage sludge drying methods, and the final disposal or use of the resulting sewage sludge. For golf courses, selection must consider management practices as well as locations to encompass both southern and northern California.
- Develop and implement monitoring plans that would capture the spatial and temporal emission patterns of N_2O from the selected sources and allow for the derivation of emission estimates. Dynamic flux chambers, wind tunnels, or open-path Fourier transform infrared (OP-FTIR) with back trajectory modeling are the preferred monitoring methods. Measurements of other gases that are of environmental significance, such as NH_3, NO_x, CH_4, VOCs, etc., should also be included if possible. Collection of associated ancillary data, such as total Kjeldahl-N and N speciation, total organic and dissolved organic carbon (DOC), total solids, pH, biochemical oxygen demand (BOD), dissolved oxygen (DO), etc. and environmental variables should be conducted, where applicable, to facilitate data interpretation. For urban landscape emissions, urban fertilizer sale and use data in California should also be collected to apportion its contribution to the total emissions.
- Conduct surveys of landfill and wastewater treatment practices and urban landscape (especially golf course) management in California to develop statewide management database or statistics so that results of this project can be scaled up to estimate statewide emissions and incorporated into future California N_2O inventory.
- Develop technical recommendations on potential mitigation measures in landfill and wastewater treatment practices and urban landscaping management that will reduce N_2O emissions from these sources.

IV. DELIVERABLES

- Quarterly progress reports and conference calls;
- Draft final report;
- Peer-reviewed publication(s), as appropriate;
- Final report and research seminar in Sacramento;
- All data and analyses generated through the course of this project;
- Additional deliverables to be determined in consultation with ARB staff.

V. Timeline and Budget

It is anticipated this project will be completed in 36 months from the start date. This allows 30 months for completion of all work through delivery of a draft final report. The last 6 months are for review of the draft final report by ARB staff and the Research Screening Committee (RSC), modification of the report by the contractor in response to ARB staff and RSC comments, and delivery of a revised final report and data files to the ARB. The estimated budget for this project is $400,000 .

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