GRADUATE AND POSTDOCTORAL STUDIES

McGILL UNIVERSITY

FINAL ORAL EXAMINATION
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

OF

Anaïs Charles
NATURAL RESOURCE SCIENCES

Chemical properties of organic amendments influence nitrous oxide emissions from agricultural soils

Thursday, February 25, 2016
9:15 am

Barton Building, Room B1-022
McGill University, Macdonald Campus

COMMITTEE:
Dr. R. T. Naylor (Pro-Dean) (Economics Department)
Dr. A. Biswas (Chair) (Natural Resource Sciences)
Dr. J. Whalen (Co-Supervisor) (Natural Resource Sciences)
Dr. P. Rochette (Co-Supervisor) (Agriculture and Agri-Food Canada)
Dr. G. Clark (Internal Examiner) (Bioresource Engineering)
Dr. Arif F. Mustafa (External Member) (Animal Science)

Dr. Josephine Nalbantoglu, Dean of Graduate and Postdoctoral Studies
Members of the Faculty and Graduate Students
are invited to attend

ABSTRACT

Prediction of organic amendment (OA) potential to emit soil nitrous oxide (POA-N_2O) is difficult because of variable composition of OAs and of complex interactions with soil properties and environmental conditions.

The objectives of this thesis were (1) to conduct a meta-analysis of on-field N_2O emissions following OA application to agricultural soils to assess global emission factor (EF) for all organic sources, $EF_{org,}$ and its modulation by environmental and management-related factors; (2) to determine how experimental conditions affect the POA-N_2O and select optimal conditions for assessment; (3) to measure the immediate (P1), short- (P2) and medium-term (P3) POA-N_2O with the selected incubation method and then, relate P1, P2, and P3 to the physico-chemical characteristics of more than 131 OAs.

The meta-analysis conducted on 422 EFs from 43 sites in 12 countries yielded EF_{org}, equal to 0.57 ± 0.30%, which is lower than the IPCC default EF of 1 for synthetic fertilizer (SF). Three groups of OAs with similar EFs were identified: the high-risk group including animal manures, waste waters and biosolids (1.09 ± 0.17%); the medium-risk group including composts + fertilizers and crop residues + fertilizers (0.46 ± 0.22%); and the low-risk group including composts, crop residues, paper mill sludge and pellets (0.25 ± 0.20%). The EF was modulated by amendment C:N ratio, soil properties and precipitations. The EFs were on average 2.8 times greater in fine-textured than coarse-textured soils.

The comparative incubation study showed O_2-limited conditions in headspace of a sealed-jar system increased the magnitude of N_2O fluxes by 1.1 to 2.3-fold compared to open-jar systems. Intermittent aerations of a sealed-jar system relying on repeated measurement periods was then selected to assess P1 (48h), P2 (2nd wk), and P3 (^{3rd} wk).

In O_2-limited conditions created in a Kamouraska clay soil, maximum P1 was reached for crop residues (CR) with C/N ratio < 15 and liquid manure. Liquid manure (LM) P1 was five-fold greater than solid manure (SM) P1, whereas P2 and P3 were higher in SM- than in LM-amended soils. Physico-chemical of OAs explained 23%, 27%, 27%, 56%, and 60% of variability in P1 response for SM, LM, vegetal compost, poultry manure and CR, respectively. P1 was correlated to water-extractable organic C and volatile fatty acids, NO_3^-, NH_4^+, S, equivalent alkalinity and pH of OAs ($P < 0.05$). In contrast, none of those chemical characteristics were correlated to P2 and P3, mostly suggesting the increased N_2O emissions supported by the OA-C and N substrates were short-lived.

CURRICULUM VITAE

UNIVERSITY EDUCATION

Doctor of Philosophy 2009- present
McGill university, Montreal, Canada
Research director : Dr. P. Rochette
Research co-director : Dr. J. Whalen
Research Topic: Carbon and Nitrogen Soil Dynamics
Chemical properties of organic amendments influence nitrous oxide emissions from agricultural soils : I. Global meta-analysis of on-field N_2O measurements; II. Measures and prediction in controlled conditions.

Master in vegetal biology 2005-2007
Université Laval, Québec, Canada
Research director : Dr. A. Karam
Research topic : Mine tailings reclamation
Copper speciation in a copper-mine tailing treated with two organic amendments

Engineer in Agricultural Sciences 2002-2006
Specialisation in Soils & Environment
École Nationale Supérieure d'Agronomie et des Industries
Alimentaires, Nancy, France

EMPLOYMENT

1. **Research professional, Université Laval - 2015** (6 months)
2. **Independent worker, Université Laval - 2014** (6 months)
   Effects of cover crops on cash crop yields, soil N dynamics and soil quality: a meta-analysis of cover cropping systems under temperate climate.
3. **Research assistant, Agriculture and Agri-Food Canada** - 2013 (6 months)
   Soils and Crops Research and Development Centre, Quebec city.
   Genetics and Enhancement of Perennial forage legumes
   - Bibliographic research and scientific writing.
4. **Independent worker, AAC** - 2009 (3 months)
   Soils and Crops Research and Development Centre, Quebec city.
   Indicator of risk of Canadian water contamination
   - Data processing/analysis/mapping

5. **Research assistant, GREPUL*** - 2008 (4 months)
   *Research group on drinking water, Université Laval, Quebec city.
   Presence of chlorination by-products throughout the distribution system
   - Haloacetic acids analysis in drinking water.
6. **Student in research program, INRS***, 2007-2008
   *Institut National de la Recherche Scientifique, Quebec city.
   Estimating the impact of *Lisox* technology on GHG emissions from treated pig slurry
   - Bibliographic research and scientific communications.
   - Setup of experimental design and gaseous measurements
7. **Summer employee, IRDA*** - 2007 (4 months)
   *Institut de Recherche et Développement en Agroenvironnement, Québec
   Optimization of the use of fertilizers and soil amendments in corn crops
   - On-field measurements, fertilizers application.
   - Soils nitrate analyses: comparative study of analytical methods.
   - Technical report writing: the use of paper mill sludges as amendment.
8. **Research Professional**, **Université Laval** - 2006 (2 months)
   Department of Soil and Agri-Food Engineering, Quebec city.
   Quantifying antibiotics run-off from agricultural fields in surface water
   - Adaptation of the *Walkley & Black method*
9. **Research trainee, Université Laval** - 2006 (6 months)
   Soil and Agri-Food Engineering & Horticultural Research Center
   Optimization of the fertilization NPK in organic greenhouse tomato production: a comparative study of commercial organic fertilizers' effects on the soil mineralization potential
   - Experimental setup and measurements on incubated soils.
   - Chemical and microbiological soil analyses.
   - Statistical analyses and scientific writing.
10. **Research trainee**, **Université Laval** - 2005 (4 months).
    Department of Wood and Forest Sciences
    Identification of environmental factors impacts on forest productivity
    - Construction of a database on Quebec soils properties (chemical composition) for mapping using data collected over 50 years by the Ministère des Ressources Naturelles et de la Faune du Québec.

AWARDS

SCHOLARSHIPS

2013	Centre SÈVE Scholarship (inter-institutional co-supervision)
2009	The Provost's Grad Fellow-AG from McGill university

STUDENT TRAVEL AWARDS

2013	The AQSSS student travel bursary
2010	The Centre SÈVE conference travel grant
2010	McGill Graduate Research Enhancement and Travel
2009	The AQSSS student travel bursary

COMMUNICATION AWARDS

2013	The Roger Baril Award (AQSSS)
2010	The SSSA Graduate Student Poster Competition S03 Division of Soil Biology and Biochemistry
2009	The CLRA student award
2006	The CLRA student award
2006	The Régis Simard Award (AQSSS)

PEER REVIEWED PUBLICATIONS

Suzanne E. Allaire, Humaira Dadfar, Jean-Thomas Denault, Eric van Bochove, **Anais Charles**, George Thériault. (2011) Development of a method for estimating the likelihood of finger flow and lateral flow in Canadian agricultural landscapes. Journal of Hydrology, Vol. 403, no. 3, pp. 261-277.

Humaira Dadfar, Suzanne E. Allaire, Eric van Bochove, Jean-Thomas Denault, Georges Thériault, **Anaïs Charles**. (2010) Likelihood of burrow flow in Canadian agricultural lands. Journal of Hydrology, Vol. 386, no. 1, pp. 142-159.

Charles, A. and A. Karam. 2006. Availability of copper in a copper mine tailing amended with mycorrhizae substratum and inorganic fertilizer. In: CLRA (Ed.) Reclamation and Remediation: Policy to Practice. Proceedings of the 31st annual meeting & conference of the Canadian Land Reclamation Association (CLRA) and the 9th Meeting of the International Affiliation of Land Reclamationists (IALR), Ottawa, Canada, pp.669-978.

SELECTED PRESENTATIONS

ORAL PRESENTATION

Charles, A., Rochette, P., Whalen, W., Parent, L.-E., Angers, D. and M. Chantigny. Apport d'amendements organiques aux sols agricoles et émissions de N_2O : une méta-analyse. 27ème Congrès annuel de l'AQSSS, *Les sols à bout de souffle?,* Chicoutimi, Québec, 27-30 mai 2013.

Charles, A., Rochette, P., Whalen, W., Angers, D., M. Chantigny and N.

Bertrand. Comment définir le potentiel d'émission de N_2O des amendements organiques? Proposition d'une méthode standard. 25ème Congrès annuel de l'AQSSS, *Sciences du sol au 21e siècle : défis à relever pour une ressource à préserver,* Wendake, Québec, 25-27 mai 2011.

POSTER'S FORM

Charles, A., Rochette, P., Whalen, W., Angers, D., M. Chantigny and N. Bertrand. The determination of relative organic amendment potential for soil N_2O emissions: Towards a standard method. ASA, CSSA, and SSSA 2010 International Annual Meetings. Green Revolution 2.0: Food+Energy and Environmental Security. Long Beach, CA, USA, 31 Oct. - 3 Nov., 2010. Clic!

Charles, A.. et A. Karam. Indian mustard response to compost amendment on a copper-mine tailing. Joint Annual Conference of the CSSS/CSA/CSAFM. *Sciences for Sustainability. Soil, Agronomy, Atmosphere.* University of Guelph, August 5 – 7, 2009. Clic!

Charles, A.., Karam, A. and A. Jaouich. Impact of commercial garden growth substratum and NPK-fertilizer on copper fractionation in a copper-mine tailing. EGU General Assembly 2009. Vienna, Austria, April 19 –24, 2009. Clic!

Charles, A.et A. Karam. Mise en végétation d'un stérile minier provenant d'un gisement de cuivre au moyen d'amendements organiques et minéraux. 75ème Congrès de l'Association francophone pour le savoir, Université du Québec à Trois-Rivières, 2007. Clic!

Charles, A. et A. Karam. Disponibilité du cuivre dans un résidu minier amendé avec des matériaux biologiques. 20ème congrès annuel de l'Association Québécoise des Spécialistes en Sciences du Sol (AQSSS), McGill university, Montreal, June 6 – 8, 2006. Clic!

Charles, A. and A. Karam. Availability of copper in a copper mine tailing amended with mycorrhizae substratum and inorganic fertilizer. 31st annual meeting & conference of the Canadian Land Reclamation Association (CLRA) / 9th Meeting of the International Affiliation of Land Reclamationists (IALR), Ottawa, Canada, August 20 – 23, 2006.

ACTIVITIES AND SERVICE

SCIENTIFIC MEMBERSHIPS

AQSSS, Association Québécoise des Spécialistes en Sciences du Sol
CSSS, Canadian Society of Soil Science
CSA, Canadian Society of Agronomy
SSSA, Soil science Society of America
CLRA, Canadian Land Reclamation Association

PEER REVIEWED

Journal of Environmental Quality