A REVIEW OF ON-GOING EMISSION FACTOR DEVELOPMENT EFFORTS FOR FARM-SCALE EMISSIONS TO THE ATMOSPHERE

Franco DiGiovanni and Ryan Glover,
AirZOne Inc., 2240 Speakman Drive, Mississauga ON L5K 1A9
Ph: 905-822-0946, Fax: 905-822-3637, email: info@airzoneone.com, url: www.airzoneone.com

The environmental impacts of farming activities are coming under closer scrutiny. Considerations usually applied to quantify emission sources from the industrial sector are now being applied to agricultural activities. Among a number of impacts being investigated, odour impact assessments are receiving more attention as urban areas encroach upon rural areas. Odorous emissions form a sub-set of total airborne emissions from farms, including greenhouse gases as well as aero-microbial emissions. An important aspect of considering the impacts of air emissions is quantifying emissions.

We will review and explain various projects across N. America aimed at deriving emission factors to aide quantification of emissions from farming activities. We will explain the background behind these (largely government-based) efforts from various jurisdictions. In particular, we will discuss the implications of this work for regulatory frameworks addressing airborne emissions from farms, and provide an analysis of future directions that they might dictate.

A Review of Atmospheric Emission Predictors for Farm Emissions

Franco DiGiovanni
Ryan Glover
AirZOne Inc.
www.airzoneone.com

Most Important Emissions

Emissions	Global, National, Regional	Local, Property Line, Nearest Dwelling	Primary Effects of Concern
NH_3	Major	Minor	Atmospheric deposition
N_2O	Significant	Insignificant	Global climate change
NO*x*	Significant	Minor	Haze
CH_4	Significant	Insignificant	Global climate change
VOCs	Insignificant	Minor	Quality of human life
H_2S	Insignificant	Significant	Quality of human life
PM10	Insignificant	Significant	Haze
PM2.5	Insignificant	Significant	Health, haze
Odor	Insignificant	Major	Quality of life

"Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs"

What are Emission Estimators?

- Definition – equations predicting emissions per unit process throughput (per animal units or per animal mass)
- How derived – correlation between emissions and throughput at a number of localities – variability, accuracy and “worst-case” estimates
- Emission Factors (EFs) vs Regression Analysis (RAs) vs Process-based Models (PBMs)

Why Used and Why Important

- Why not just measure emissions?
- Regulatory community: info to define and support feasible regulation
- Farming community: specific emission values to define impacts of their operations on nearby sensitive receptors

Emission Predictions

- Climate - temperature, rainfall frequency and intensity, wind speed, topography, and soils
- Temporal – hourly, daily and seasonal
- Animal life stage – changes in feed, e.g., 2x's increase in N excreted in grow-finish hogs
- Management – feeds, routines

Emission Factors

$$E = \sum_i (w_i \bullet e_i)$$

e.g., a 40,000 head cattle feedyard with an emission factor of 127 kg TSP per thousand head per day produces 1,854 TSP tonnes per year

- too few data to be confident (NRC)
- US EPA “model farm (classes)” concept

Methane

- regression analysis approaches

e.g., Methane (megajoules per day) = 3.406 + 0.510 (cell solubles) + 1.736 (hemicellulose) + 2.648 (cellulose).

(Enteric methane production based upon dietary intake (cattle))

Methane from Manure Storage - Process-based modelling

$$TM_{CH_4} = \Sigma VS_i * B_{0i} * MCF_j * WS_{ij} * CAF$$

where

TM_{CH_4} = total annual methane emission from manure storage on the farm in cubic meters of CH_4 per year;

VS_i = volatile solids produced annually by animal *i* in kilograms;

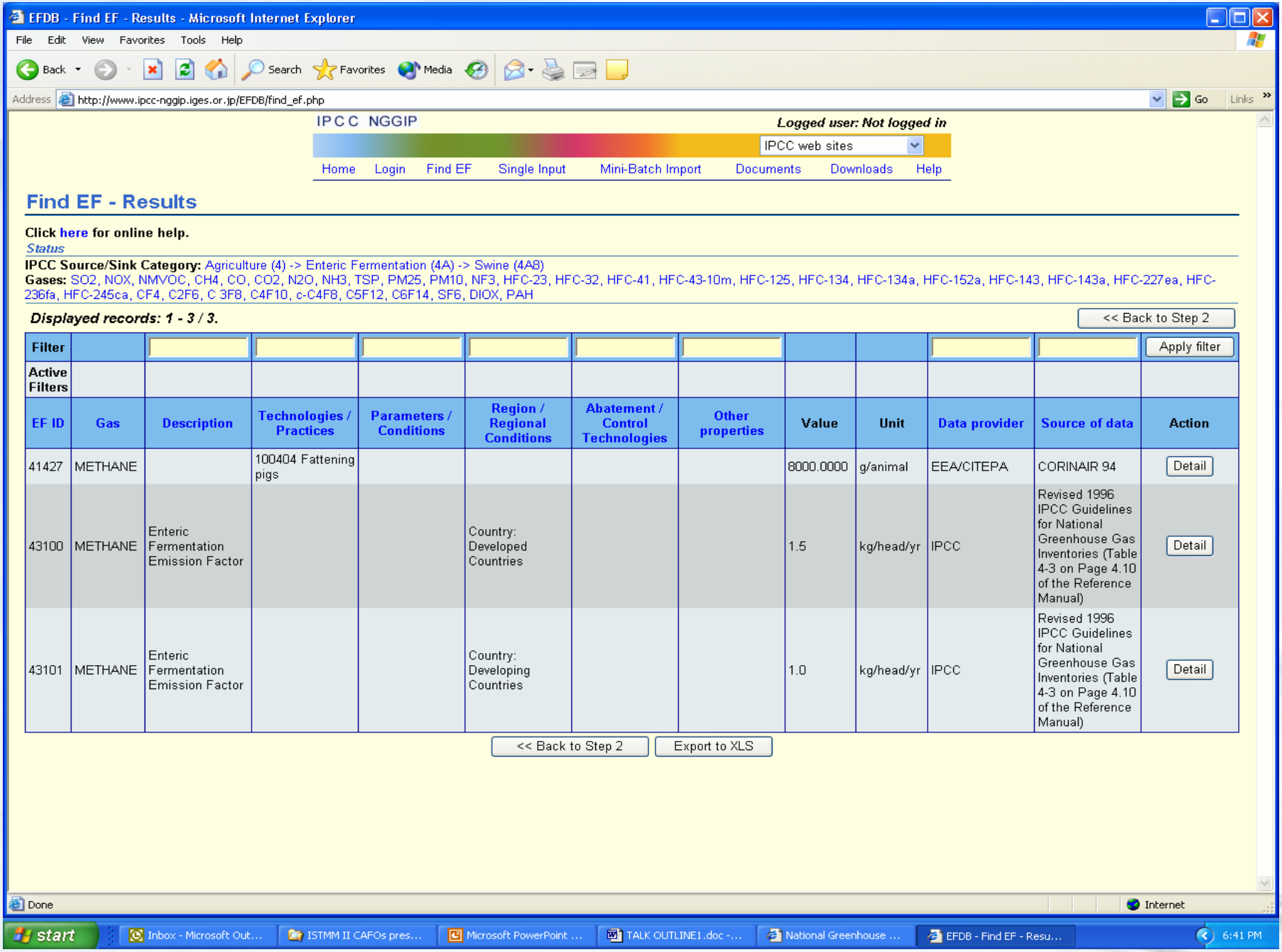
B_{0i} = maximum methane production potential of the manure from animal *i* in cubic meters of CH_4 per kilogram of VS;

MCF_j = methane conversion factor for manure storage *j*, which represents the extent to which B_0 is realized (*note*: $0 \leq MCF \leq 1$);

WS_{ij} = fraction of animal *i*'s waste handled in the manure storage *j*; and

CAF = climate adjustment factor for the farm, which represents the extent to which B_0 is realized under climatic conditions (e.g., temperature, rainfall) on the farm (*note*: $0 \leq CAF \leq 1$).

IPCC Emission Factors



Ammonia

- Process-based model (NRC)
- US EPA (Jan. 2004) inventory of ammonia emissions based upon process-based model and manure management trains (MMTs)
- MMT consists of an identified farm-system
- Over 18 different MMTs were developed for this inventory

Odour

- Odour - Schiffman et al. (2001) identified 331 odour-causing compounds in swine manure.
- e.g., Hobbs et al. (2001) developed a correlation between human olfactory response and an odour mixture of four gases.
- Predicting odour emissions not reliable at this stage – can only measure

Particulate Matter

- EFs still used (e.g, CARB permitting of dairies)
- CARB assumed that dairy operations = cattle feedyards
- Overestimate: dairy cattle PM_{10} emission factor would be <20% of the cattle feedyard PM_{10} emission factor.

H_2S from Manure Storage - Process-based modelling

$$TM_{S^-,k} = \sum S_i \bullet S_{0i} \bullet SCF_j \bullet WS_{ij} \bullet CAF \bullet t_k$$

where

$TM_{S^-,k}$ = total sulfide production from manure storage on the farm in grams of sulfide per day, for day *k*;

S_i = sulfur excreted by animal *i,* plus sulfur per animal added from the water supply, in grams per day;

S_{0i} = maximum sulfide production potential of the manure from animal *i* in grams of sulfide per gram of sulfur;

SCF_j = sulfur conversion factor for manure storage *j*, which represents the extent to which S_0 is realized (*note*: 0≤SCF≤1);

WS_{ij} = fraction of the animal *i*'s waste handled in the manure storage *j*;

CAF = climate adjustment factor for the farm, which represents the extent to which S0 is realized under climatic conditions (e.g., temperature, rainfall) on the farm (*note*: 0≤CAF≤1);

t = time (day); t_k is *k*th day in the manure storage.

Bioaerosols

- Bioaerosols – what they are
- health affects (allergenic, pathogenic, toxigenic)
- measurement and monitoring challenges

Regulatory Issues

- GHG emissions – Kyoto impacts on farming
- Local issues – Odour (*nuisance*)
- Local issues – PM, H_2S, Bioaerosols (Health impacts)

Ontario - Odour

- MSD I & II and Sample By-Law (OMAF)
- One step further – emission estimates, dispersion models and impact assessments
- Ontario EPA Part II Section 6 subsection 2 exempts manure
- Pollutant complaint – under FFPPA (not a “Right to Farm” Act)
- Normal Farm Practices Protection Board
- Does not cover “harmful” emissions

Summary

- NRC – US EPA: towards Process-based modelling
- IPCC – still using EFs
- Various others – e.g. CARB
- Other useful sources of information – Canadian Soc. Ag. Meteorology
- Local health impacts may drive future regulatory action

Thank you

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