DAIRY AIR EMISSIONS ANALYSIS:
Focus: Ammonia emissions
for
TYPICAL DAIRY MANAGEMENT SYSTEMS in IDAHO

SUMMARY of METHODOLOGY and FINDINGS:
TECHNICAL REFERENCE DOCUMENT
Final Draft

DEVELOPED in a COLLABORATIVE NEGOTIATION
Between:

ICL (IDAHO CONSERVATION LEAGUE)
and
IDEAL (INDEPENDENT DAIRY ENVIRONMENTAL ACTION LEAGUE)

FEBRUARY 10-11, 2005

BOISE, IDAHO

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INTRODUCTION

Idaho Conservation League (ICL) and Independent Dairy Environmental Action League (IDEAL) negotiated air quality emission factors, defined for three different dairy management systems, predominant in the Idaho dairy industry. The three different systems include:

- open lot
- free stall scrape
- free stall flush

Ammonia (NH_3) emissions were the focus of the discussion and analysis and the only air pollutant for which threshold herd sizes were defined through the negotiation process between ICL and IDEAL.

Open lot and free stall scrape dairies were further defined regarding land application options with respect to ammonia emissions.[1] Three different land application options were defined, including:

- no land application of manure at the facility
- center pivot or other conventional sprinkler irrigation liquid manure application
- drop-hose or other ground-level liquid manure application.

Ammonia emission factors are influenced by several variables. As a nitrogen-based compound, the potential for ammonia emissions start with the amount of nitrogen ingested in the ration fed to dairy herds. Recent research published by the American Society of Agricultural Engineers (ASAE) includes manure nitrogen excretion values that reflect variations in the milk production rate in dairies (January 2005, and "ASAE D384.1, Manure Production and Characteristics, 2003").

After accounting for the utilization of nitrogenous compounds by the dairy animal for milk production, maintenance, growth and excretion, the resulting production of ammonia emissions are most influenced by the type of dairy operation (housing and manure management systems) and methods of land application of manure nutrients. Generally, using a flush system volatilizes a higher percentage of the nitrogen as ammonia than dry or semi-solid, manure management systems. Therefore, dairies using free-stall flush systems require

[1] Emissions from free stall flush dairies could be further refined based upon types of land application techniques, but such refinement would have no practical consequence in Idaho, as all free stall flush dairies in Idaho are larger than the threshold for that dairy management system.

fewer animals to reach 100 tons of ammonia emissions than dairies using free-stall scrape or open-lot animal management systems.

Please note that the analysis and findings presented herein have not been peer-reviewed.

SUMMARY OF FINDINGS and CONCLUSIONS

As a result of the technical presentations, discussions and negotiations (February 10-11, 2005), the following threshold dairy herd sizes were agreed to that would likely produce an estimated 100 tons of ammonia per year. The table below depicts the herd size based upon total mature (average: 1400 lbs. bodyweight) cows (milking and dry, assuming, 85% of cows in milk and 15% dry cows). Since there is a wide variety of dairy replacement heifer raising systems used throughout Idaho, the threshold herd sizes were agreed to based upon mature dairy cows and the associated Animal Units (AU = 1000 lb. bodyweight, therefore, each mature cow (milking and dry) represented 1.4 AU).

Table 1. Dairy herd threshold size (animal unit (AU) and mature cow (1400 lbs. BW) basis – projected to emit 100 tons of NH_3 per year)

Animal Unit (AU) Basis	Drylot	Free Stall/Scrape	Free Stall/Flush
	AU (100 t NH_3) threshold		
No land app	7089	3893	2293
27% volatilization [1]	6842	3827	
80% volatilization [2]	6397	3700	
Cow Basis (1400 lbs. bodyweight)	Drylot	Free Stall/Scrape	Free Stall/Flush
	Total cows (100 t NH_3) threshold		
No land app	5063	2781	1638
27% volatilization [1]	4887	2733	
80% volatilization [2]	4569	2643	

[1] *Assumes*: Expected level of N->NH_3 volatilization for: **drop-hose or other ground-level liquid manure application**

[2] *Assumes*: Expected level of N->NH_3 volatilization for: **center pivot or other conventional sprinkler irrigation liquid manure application**

Air emissions from dairy production systems is an area of active research in several locations throughout the US and internationally. As these findings

provide new and refined insights into the collective knowledge-base, and as dairy systems adapt to reduce emissions and improve operational and capital efficiencies, these threshold herd sizes and assumptions used to develop these will need to be reviewed and revised on an ongoing basis.

ASSUMPTIONS and SUPPORTING ANALYSIS USED to ARRIVE at HERD SIZE THRESHOLDS by DAIRY SYSTEM

Figure 1 (below) represents EPA-based emissions estimates (2004) for a range of dairy systems (housing and manure management) and land application strategies. In all cases the emission estimates used were for the greater than 200 head operations. The pounds of ammonia produced were initially based on the lower (.45 lb/au/day) estimates as shown. These emissions rates were increased to reflect the new ASAE estimates that will be used from this point forward.

Figure 1. EPA Emission Factors 2004 for Three Types of Dairy Operations

	A	E	F	G	H	I	J	K
1	**Idaho Conservation League**							
2	**K&W Dairy Niagra Farms Negotiation**							
3	Air Emission Factor Research							
4	Prepared by USKH, Inc., Alan E. Gay (AEG), PE							
5	February 11, 2005							
6								
7	EPA 2004 Emission Factor Calculations							
8	Basis for conversion from NH3 to N is "rule-of-thumb" for ammonia emissions as a percentage of total N emissions.							
9								
10						**lb/hd/year**	**lb/hd/year**	**lb/hd/year**
11						**.45 lb/au/d**	**.45 lb/au/d**	**.45 lb/au/d**
12				**AEG**		**>200 head**	**>200 head**	**>200 head**
13		**EPA**	**EPA**	**percent**	**estimated**	**Type 1 Dairy**	**Type 2 Dairy**	**Type 3 Dairy**
14		**lb/hd/year**	**percent**	**estimated**	**percent**	**Flush Barn**	**Scrape**	**Drylot**
15		**NH3**	**N emitted**	**NH3 as N**	**NH3 as N**	**229.95**	**229.95**	**229.95**
16	**Dairy Flush Barn**	NA	23.5	90	21.15	41.34		
17	**Scrape Barn**	18.5	NA				18.50	
18	**Outdoor Confinement Areas**	NA	8	80	6.40			
19	**Drylots**	18.58	NA					18.58
20	**Deep Pits**	NA	28.5	50	14.25			
21	**Lagoons**	NA	71	50	35.50	57.16	10.78	12.24
22	**Tanks**	NA	6.6	50	3.30			
23	**Stockpile**	NA	20	50	10.00	2.76	18.11	
24	**Liquid Land Application (>200 head)**	NA	24	80	19.20	19.94	3.76	4.27
25	**Solid Land Application (>200 head)**	NA	19	10	1.90	0.47	3.10	3.36
26	**Liquid Land Application (100-200 head)**	NA	22	80	17.60			
27	**Solid Land Application (100-200 head)**	NA	18	10	1.80			
28	**Liquid Land Application (<100 head)**	NA	24	80	19.20			
29	**Solid Land Application (<100 head)**	NA	19	10	1.90			
30				Totals w/ Land App->		**121.67**	**54.24**	**38.46**
31								
32				Land App Only Total->		**20.41**	**24.97**	**7.63**

Figure 2 (below) reflects the updated typical nitrogen excretion rates for milking cows at four different levels of milk production, dry cows, calves and heifers and corresponding ammonia losses (10-90%) as a percent of excreted nitrogen. These higher nitrogen excretion rates were used in the calculation and eventual determination of threshold herd sizes for the three dairy systems considered.

Figure 2. ASAE 2005 N Excretion for dairy animals

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Nitrogen excretion rate based upon 2005 ASAE Standards (in final draft) for typical animals												
2													
3					Ammonia Loss (% of excreted nitrogen)								
4		Milk/day		Typical N excretion (lbs per animal per day)	10%	20%	30%	40%	50%	60%	70%	80%	90%
5	Dairy - Lactating cow - 100 lbs milk/day	100		**1.04**	0.104	0.208	0.312	0.416	0.520	0.624	0.728	0.832	0.936
6	Dairy - Lactating cow - 88 lbs milk/day	88		**0.99**	0.099	0.198	0.297	0.396	0.495	0.594	0.693	0.792	0.891
7	Dairy - Lactating cow - 70 lbs milk/day	70		**0.83**	0.083	0.166	0.249	0.332	0.415	0.498	0.581	0.664	0.747
8	Dairy - Lactating cow - 50 lbs milk/day	50		**0.66**	0.066	0.132	0.198	0.264	0.330	0.396	0.462	0.528	0.594
9	Dairy - Dry cow			**0.50**	0.050	0.100	0.150	0.200	0.250	0.300	0.350	0.400	0.450
10	Dairy - Milk fed calves			**0.02**	0.002	0.003	0.005	0.007	0.009	0.010	0.012	0.014	0.015
11	Dairy - Calf			**0.14**	0.014	0.028	0.042	0.056	0.070	0.084	0.098	0.112	0.126
12	Dairy - Heifer			**0.26**	0.026	0.052	0.078	0.104	0.130	0.156	0.182	0.208	0.234

Since the new ASAE, 2005 nitrogen excretion rates (which are based to a great extent on the National Research Council (NRC) Nutritional Requirements of Dairy Cattle, account for the level of milk production, which earlier estimates did not take into account. In order to arrive at a representative level of milk production for Idaho dairy farms, the USDA National Agricultural Statistics Service (USDA-NASS) numbers were reviewed for the most recent four years shown in the Figure 3 below. The average 2003 milk/cow/day was 59.5 lbs., so it was agreed to use linear interpolation and based the nitrogen excretion rates on 60 lbs./cow/day average.

Figure 3. USDA-NASS Idaho Milk Production - 2000-2003 and Average Milk/Cow/Day

Year	Milk/cow/yr	Milk/cow/day
2003	21718	**59.5**
2002	21018	57.6
2001	21194	58.1
2000	20816	57.0

Year	State	Region	Annual Milk Production, Milk Cows, and Milk per Cow		
			Production	Milk Cows (Average)	Milk Produced per Cow
			mill lbs	1000 Head	pounds
2000	ID	20 States	7223	347	20816
2001	ID	20 States	7757	366	21194
2002	ID	20 States	8155	388	21018
2003	ID	20 States	8774	404	21718

Figure 4. depicts a graphical representation of the nitrogen (N) excretion for the range of milk production levels (50 – 100 /lbs./cow/day) indicating a reasonably linear relationship between milk production levels and N excretion until reaching the 88-100 lb./cow/day levels. Therefore, as depicted in Figure 5, the typical nitrogen excretion rate for the Idaho average level of milk/cow/day of 60 lbs., interpolates to 0.745 lbs. N per cow per day, which was used instead of the previous level of excretion of 0.63 lbs. N per cow per day (shown in Figure 1, where, 0.45 lbs./cow/day *1.4 AU = 0.63 lbs./cow/day)

Figure 4. Graphical representation of ASAE, 2005 N excretion by level of milk production

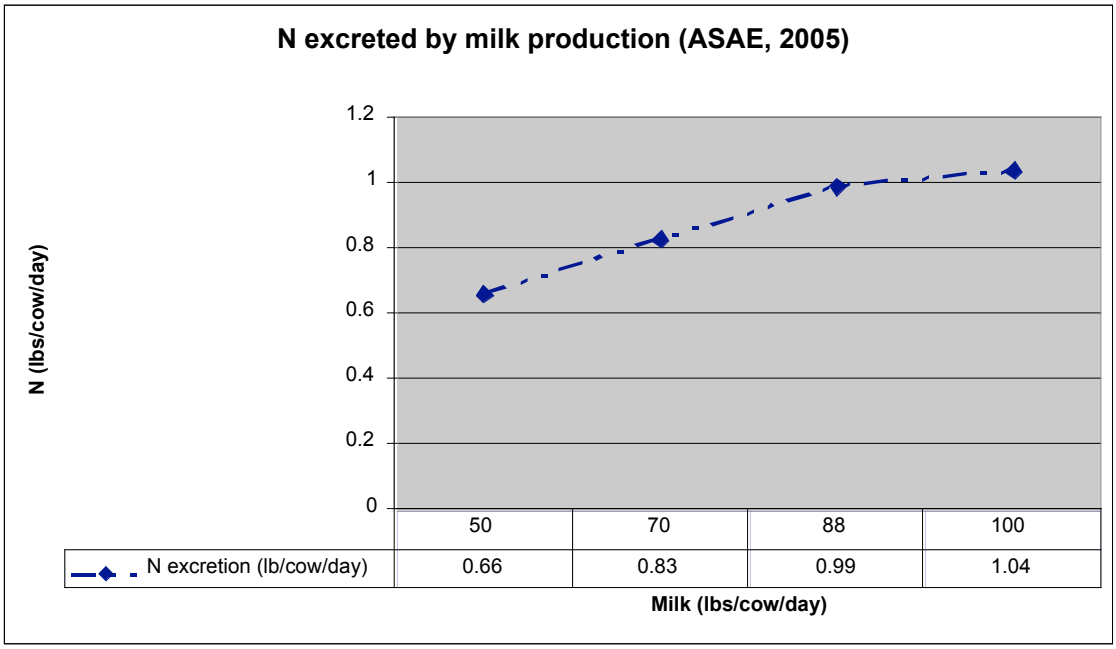

Figure 5. Linear interpolation of N excretion for 60 lbs. milk/cow/day (ID average production)

Milk (lb/cow/day)	N excretion (lb/cow/day)		Interpolation (for level of milk production	
50	**0.66**		**60**	**0.745**
70	**0.83**			
88	0.99			
100	1.04			

Figure 6 shows the typical ammonia losses for animal housing and storage systems that were considered in the analysis of ammonia losses across the three representative Idaho dairy systems.

Figure 6. Typical ammonia losses for animal housing and storage systems

Table 1. Typical ammonia losses from animal housing facilities expressed as percentage of excreted nitrogen

Facility	% loss range
Open dirt lots (cool, humid region)	15-30
Open dirt lots (hot, arid region)	30-45
Roofed facility (flushed or scraped)	10-20
Roofed facility (shallow pit under floor)	10-20
Roofed facility (bedded pack)	20-40
Roofed facility (deep pit under floor)	15-30

Table 2. Typical ammonia losses from manure storage as a percentage of nitrogen entering facility

Facility	% loss range
Temporary stacked manure (no turning)	10-20
Composted manure (no carbon amendment)	30-40
Composted manure (w/ sig carbon amend.)	5-10
Bedded pack manure (included in Table 1)	0
Runoff holding pond (perciptation runoff only)	2-3
Pit below slatted floor (included in Table 1)	0
Earthern storage pit (minimal treatment)	20-35
Formed manure storage (bottom load)	10
Formed manure storage (top loaded)	30
Anaerobic lagoon (sig, treatment)	70-85

Figure 7 represents the results of our analysis and discussion as extracted from the final Excel spreadsheet used to summarize our findings and the resulting agreement as to these threshold levels for herd size by system. These same results are shown in Table 1 (page 4). The assumptions made for land

application contributions to NH3 emissions were based on the following assumptions and Figure 1 (page 5):

- The 28% N volatilization is based on the expected level of N->NH_3 volatilization for: drop-hose or other ground-level liquid manure application
- The 80% N volatilization is based on the expected level of N->NH_3 volatilization for: center pivot or other conventional sprinkler irrigation liquid manure application

Figure 3. SUMMARY: Animal Unit (AU) or mature cow threshold to produce 100 ton NH3/year

AU Basis	Drylot	FS/Scrape	FS/Flush
	Animal Units (100 t NH3) threshold		
No land app	7089	3893	2293
27% volatilization	6842	3827	
80% volatilization	6397	3700	
Cow basis (1400 lbs)	Drylot	FS/Scrape	FS/Flush
	Total cows (100 t NH3) threshold		
No land app	5063	2781	1638
27% volatilization	4887	2733	
80% volatilization	4569	2643	

Figures 8, 9 and 10 (below) represent the component and summary calculations used to base the recommendations contained in Table 1/Figure 7, for the three dairy systems most typical of the Idaho dairy industry.

Figure 4. NH3 Production for Drylot System - with and without Land Application

1	FINAL SPREADSHEET (ICL-IDEAL) - Feb 10-11, 2005 DISCUSSIONS/NEGOTIATIONS						
2	DRYLOT	# animals	% day	N excreted/day	N lbs/day	N lbs/yr	N tons/yr
3	Milk cows	850	85%	0.745	538	196466	98.2
4	Dry cow	150	100%	0.500	75	27375	13.7
5	Heifers	0	100%	0.260	0	0	0.0
6	TOTAL N	1000			613	223841	111.9
7	Milking cows (milking center)	850	15%	0.745	95	34670	17.3
8	TOTAL COWS	1000					
9	AU	1400					
10	TOTAL FACILITY N Production				708	258511	129
11		% loss			N lbs/day	N lbs/yr	N tons/yr
12	Open lot NH3 loss %	15%			92.0	33576	16.8
13	Holding pond (winter - 5 mos)	20%			7.9	2889	1.4
14	Holding pond (7 mos)	15%			8.3	3034	1.5
15	TOTALS					Tons/herd/yr	19.7
16						Lbs/au/yr	28.2
17						Lbs/cow/yr	39.5
18	Land application	80% volatilization N			4.27		2.1
19		27% volatilization N			1.42		0.7
20				Without land application		# cows @ 100t	5063
21						# AU @ 100t	7089
22				With land application 27% volatilization		# cows @ 100t	4887
23						# AU @ 100t	6842
24				With Land application 80% volatilization		# cows @ 100t	4569
25						# AU @ 100t	6397

Figure 5. NH3 Production for Free-Stall/Scrape System - with and without Land Application

1	FINAL SPREADSHEET (ICL-IDEAL) - Feb 10-11, 2005 DISCUSSIONS/NEGOTIATIONS						
48	FREE-STALL/SCRAPE	# animals	% day	N excreted/day	N lbs/day	N lbs/yr	N tons/yr
49	Milk cows	850	85%	0.745	538.3	196465.8	98.2
50	Dry cows	150	100%	0.500	75	27375	13.7
51	Heifers	0	100%	0.260	0	0	0
52	TOTAL N						111.9
53	Milking cows (milking center)	850	15%	0.745	95	34670	17.3
54	TOTAL COWS	1000					
55	AU	1400					
56		% loss			N lbs/day	N lbs/yr	N tons/yr
57	Free-stall				43.08	15725.0	7.9
58	Lagoon	20%			2.95	1078.5	0.5
59	Solids stockpile	10%			56.01	20442.5	10.2
60							
61	TOTALS					Tons/herd/yr	35.96
62						Lbs/au/yr	51.4
63						Lbs/cow/yr	71.9
64	Land application	80% volatilization N			3.76		1.9
65		27% volatilization N			1.25		0.6
66				Without land application		# cows @ 100t	2781
67						# AU @ 100t	3893
68				With land application 27% volatilization		# cows @ 100t	2733
69						# AU @ 100t	3827
70				With Land application 80% volatilization		# cows @ 100t	2643
71						# AU @ 100t	3700

Figure 6. NH3 Production for Free-Stall-Flush System - with and without Land Application

1	FINAL SPREADSHEET (ICL-IDEAL) - Feb 10-11, 2005 DISCUSSIONS/NEGOTIATIONS						
74	FREE-STALL/FLUSH	# animals	% day	N excreted/day	N lbs/day	N lbs/yr	N tons/yr
75	Milk cows	850	85%	0.745	538.3	196465.8	98.2
76	Dry cows	150	1	0.5	75	27375	13.7
77	Heifers	0	1	0.26	0	0	0
78	TOTAL N						111.9
79	Milking cows (milking center)	850	15%	0.745	95	34670	17.3
80	AU	1400					
81		% loss			N lbs/day	N lbs/yr	N tons/yr
82	Free-stall/flush	21%			113.04	41257.8	20.6
83	Lagoon	20%			111.45	40680.0	20.3
84	Solids stockpile	10%			15.10	5511.1	2.8
85							
86	TOTALS					Tons/herd/yr	61.1
87						Lbs/au/yr	87.2
88						Lbs/cow/yr	122.1
89				Without land application		# cows @ 100t	1638
90						# AU @ 100t	2293
91				With land application		# cows @ 100t	1638
92						# AU @ 100t	2293

REFERENCES

A comprehensive set of references (including the full text of the reference in most cases) used by ICL and IDEAL resource experts is contained on the following website:

http://www.DairyStrategies.info/icl-ideal

Userid: icl

Password: gotmilk