

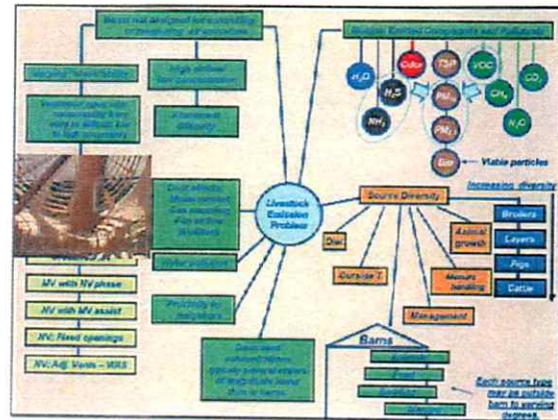
### National Study of Livestock Air Quality in USA

ISHEAW, Chongqing, China, October 21, 2011


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### Citizen's Odor Nuisance Suits

- Neighbors seek for:
  - Actual damages
  - Punitive damages
  - Injunction to close the operation
  - Court order for abatement of odour
- Ohio
  - Nuisance suit v Buckeye Egg Farm, 2001, \$19.7M
- Missouri
  - 52 neighbors v. Continental Grain: \$5.2M award
  - 60 nuisance suits against Premium Standard Farms, last 10 years

Sources: Miner, 1997; van Sickle, 2003; Lee, 2004

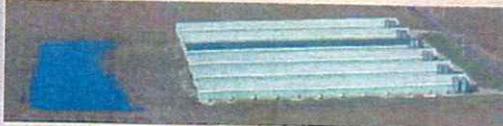
### State Odor Regulations

- Indirect Regulations
  - Permits (odor management plans)
  - Setbacks (minimum buffer distances)
  - Operator training (certification)
  - Land application restrictions (inject)
- Direct Regulations
  - 10 states (Redwine and Lacey, 2000)
  - Property line limits
    - Field olfactometry readings (2-8 D/T)
    - Gas concentrations (H<sub>2</sub>S and NH<sub>3</sub>)
- Lawsuits and consent decrees

NASAL RANGER 

### State Lawsuits

- Missouri v. Premium Standard Farms, 1999
  - \$650,000 fine
  - \$25M for "Next Generation" technologies
- Ohio v. Buckeye Egg Farms, 2001
  - \$1,000,000 fine
  - Must convert deep pit barns to belt-batteries
  - Revoked operating permits, July, 2003
  - Closed down one facility, November, 2003



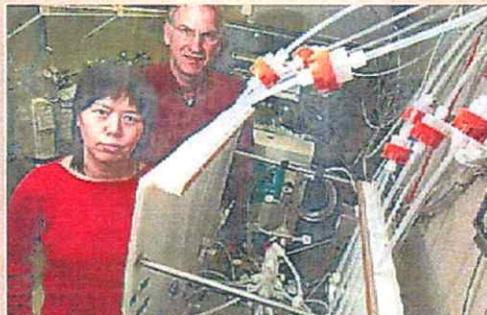
### Federal Lawsuits (Authority: U.S. Clean Air Act of 1990)

- U.S. v. Premium Standard Farms, 2001
  - Air and water
  - \$350,000 penalty
  - Lagoon emission monitoring
  - Barn monitoring tests, six (6) months long
  - Test soybean oil sprinkling in one (1) of the barns.
- U.S. v. Buckeye Egg Farms, 2004
  - Air issues
  - \$880,000 penalty
  - Barn emissions monitoring and controls
  - Test dust and ammonia abatement
  - Brief summer tests showed 700 tpy > 250 tpy limit
  - Owners moved back to Germany

### Federal Regulations

- > EPCRA (Community Right to Know Laws)
  - > Covers NH<sub>3</sub> and H<sub>2</sub>S among others
  - > Must report if emissions ≥ 100 lbs/d (45.5 kg/day)
- > Clean Air Act
  - > "Substances of concern" (PM, VOC, etc.)
  - > National Ambient Air Quality Standards
  - > Defines "Major Source" thresholds
    - > Requires annual permit fee for major sources

**Gov't agencies needed reliable data.  
Livestock producers needed more time.**



### "Air Consent Agreement" (Jan. '05)

- > Between U.S. EPA and livestock industries
  - > Producers voluntarily paid a "penalty" based on farm size
  - > EPA "forgave" producers for past violations of U.S. air laws
  - > Producers participated in the NAEMS to get emissions data
  - > EPA develop and applies data-based emission estimations or "Emission Estimation Methodologies" (EEM)
- > National Air Emissions Monitoring Study (NAEMS)
  - > Required by Air Consent Agreement (ACA)
  - > Study approach finalized at meeting in Beltsville, MD (11/03)
  - > Overseen by U.S. EPA
  - > Funded by American Egg Board, Nat'l Pork Board, Nat'l Milk Producers Federation, and Nat'l Chicken Council via the Agricultural Air Research Council (John Thoma, Exec. V-P)
  - > Turkeys, ducks and beef cattle groups did not participate.

### 2003 "Beltsville Meeting" to Design the Study

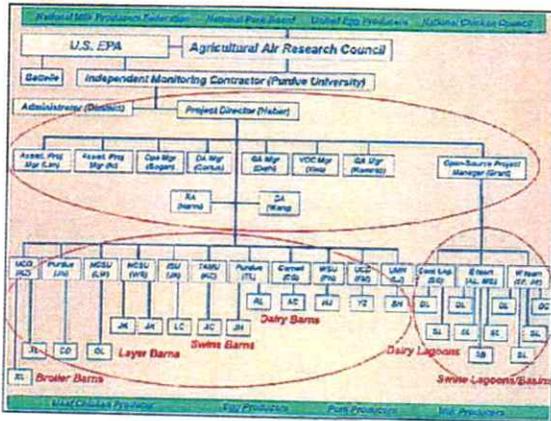
- > Intensive vs. extensive tests
- > Farm selection
- > Organizational structure
- > Whole farm vs. component tests
- > Supporting data
- > Public vs. private contractor

### General Timeline of the NAEMS

- 2004 Protocol Development and Farm Selection Criteria
- 2005 PI Selection, Staffing, Budgeting, Educating Producers
- 2006 Site Selection, Quality Assurance Project Plan
- 2007 Setup of Barn and Open Source Emission Monitoring
- 2008 Data Collection, Analysis and Reporting, Audits
- 2009 Data Collection, Analysis and Reporting, External Audits
- 2010 Prepare and Submit Final Report for EPA, Further Analysis
- 2011 EPA Develops EEMs, Further Analysis, Journal Articles
- 2012 EPA Publishes EEMs, PI's Continue Publishing

### NAEMS Principal Investigators

Poultry		
CA1B, CA2B	Hilhong Zhang	University of California - Davis
IN3B, IN3H	Jiuh Ni	Purdue University
NC2B	Linglian Wang	North Carolina State University
Swine		
IN3B	Teng Lim	Purdue University
NC3B, NC4B	Wayne Roberts	North Carolina State University
IA4B	J. Kozicki, S. Hoff	Iowa State University
OK4B	Ken Casey	Texas Agricultural Experiment Station
Open Sources	Rick Grant	Purdue University
Dairy		
CA5B	Frank Mitloehner	University of California - Davis
IN5B	Teng Lim	Purdue University
NY5B	Curt Gooch	Cornell University
WA5B	Pius Hlegwa	Washington State University - Pullman
WI5B	Larry Jacobson	University of Minnesota
Open Sources	Rick Grant	Purdue University



**Was industry-funded NAEMS "tainted" or "biased"? No!**

- Tests required by consent decrees or agreements are typically funded by firms.
- AARC addressed budget and deadlines.
- EPA addressed data quality issues.
- NAEMS followed protocols of past studies and improved methods where possible.
- PI's maintained independence/neutralty as "Independent Monitoring Contractor."

**Objectives of the NAEMS**

- Quantify air emissions from livestock production.
- Provide reliable data for developing and validating barn and lagoon emission models.
- Develop national consensus on methods of measuring, calculating, & reporting emissions.

**NAEMS Scope**

- Baseline study
- Continuous high frequency QA'd barn data for two years using mobile labs
- Pollutants (PM<sub>2.5</sub>, PM<sub>10</sub>, TSP, NH<sub>3</sub>, H<sub>2</sub>S, CO<sub>2</sub>, CH<sub>4</sub>, VOC)
- Swine, egg, broiler, and dairy houses
- Collected as much "metadata" as possible (animal activity, wind, etc.)
- 35 livestock & poultry barns tested with similar protocols
- 2300 sensors and 2.45 billion data points
- Quality assurance/quality control
  - Oversight of U.S. EPA Office of Air Quality
  - Quality Assurance Project Plan (Category 1)
    - 78 standard operating procedures (SOPs)
    - 15 barn site monitoring plans (SMPs)
    - 10 open source site SMPs
  - On-site audits
- Allowed add-on studies of odor, N<sub>2</sub>O, CH<sub>4</sub>, pathogens, and mitigation.

**NAEMS Methods**

- Comprehensive real-time barn emission data
  - Ammonia (photoacoustic, chemiluminescence, TDLAS)
  - Hydrogen sulfide (pulsed fluorescence)
  - Carbon dioxide (photoacoustic)
  - PM (tapered element oscillating microbalance)
  - Airflow (fan voltage, vibration, pressure, velocity, & flow)
  - Wind and air velocity (ultrasonic anemometers)
- Integrated sampling
  - Volatile organic compounds: GC-MS and canisters (24-h)
  - Seven 24-hour VOC samples from barn outlets (GC-MS analysis)
  - Odor samples: Tedlar bags and sorbent tubes
- Novel methods
  - NY barn airflows measured with 3-D sonic anemometers.
  - Fan operation measured with vibration sensors.
  - Custom designed data acquisition & processing systems.

**Slightly negative concentrations were "left alone"**

- Gas analyzers have noise – random up and down variation, even when measuring zero.
- Slightly negative gas concentrations occur with zero or very low concentrations. Negative gas concentrations in the NAEMS were slight.
- Similar but unnoticed noise occurs at high gas levels.
- EPA advised Purdue not to delete noise-related negatives for the emission calculations.
- Slight to large negative PM concentrations can occur at short time scales (minute, hour) due to moisture, but disappear at longer time scales (day, month, year)
  - Negative PM<sub>2.5</sub> more frequent than PM<sub>10</sub> and TSP.

**Barn inlet air was not community's ambient air.**

- Inlet air often called "ambient air" in reports.
- Inlet air sampled in building wall or few feet away from the barn(s).
- Inlet air is close to source and surrounded by other sources, thus has elevated levels.
- Inlet air far from the property line.
- Inlet air concentrations should not be compared with National Ambient Air Quality Standards (NAAQS) or other thresholds intended to protect the community.

**Exhaust concentrations do not always indicate exposure**

- Fans downstream of animal/worker area
  - High-rise houses
  - Drying tunnels at IN2B
  - Broiler houses during brooding
  - Pit fan exhausts of deep pit swine barns
- Empty barns and ventilation shut downs
- Exhaust > average concentrations
  - Belted barns
  - Tunnel ventilated barns

**NAEMS Emission Calculations**

- Measured gas/PM at barn inlets and outlets
- "Subtracted inlets" -  $E = Q(C_{out} - C_{in})$ 
  - Occasionally results in a short term "negative emission" especially when actual emissions are very low or with outside interferences.
  - Negative emission data were not invalidated.
- We did not
  - Measure inlet concentrations with VOC canisters
  - Measure neighbor exposure
  - Measure worker/animal exposure
  - Remove/adjust negative concentrations
  - Remove/adjust negative emissions

**Short term negative emissions were not removed or adjusted**

- Emission calculations are "noisy" due to:
  - Analyzer noise
  - Wind caused variations in inlet concentrations.
  - Localized activities (mowing, manure hauling, gravel roads, etc.)
  - Location-shared and nonsimultaneous sequential sampling
- Subtracting inlet introduces some negative emissions when inlet concentration > outlet concentrations
  - Low emissions
  - imperfect representation of inlet air (e.g. 1200 ft of eave inlet), interpolation of inlet air readings coupled with interpolation of outlet.
- Also introduces unnoticed high biases of emissions.
- Actual negative emissions could result from:
  - Dry scrubbing.
  - PM settling in barn.
  - Ammonia wet deposition and adsorption

**Net emissions (outlet-inlet) does not underestimate emissions.**

- Widely accepted approach in journal papers.
- Exhaust air reentry means pollutants counted multiple times if inlet is not subtracted.
- Pollutants from external sources would be credited to the barn if inlet not subtracted.
- Inlet NH<sub>3</sub>, H<sub>2</sub>S and PM<sub>10</sub> were 2 to 6% of outlet at broiler site.
- "Gross" emissions overestimate emissions.

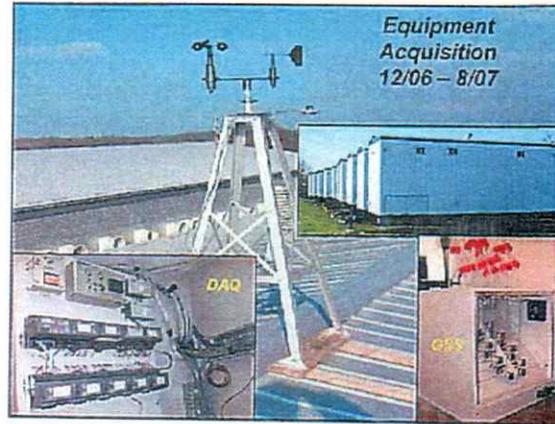
**Greater resolution (1 min vs. 1 hr vs. 1 d) may not give better information**

- Interpolated sequential gas data.
- Moisture interference of TEOM
- Analyzers have internal averaging methods.
- AirDac sampling frequency
- Depends on number of sampling points.
  - TEOM 1 point
  - Gases 3-18 points.

### Barn Site Monitoring Plans

Site ID	Title	Site ID	Title
CA1B	Brouler Ranch in California	NC4H	Sow Farm in North Carolina
CA2B	Layer Site in California	OK4H	Sow Farm in Oklahoma
IN2B	Layer Site in Indiana - Manure Helix	CA5H	Dairy Farm in California
IN2H	Layer Site in Indiana - High-Rise	IN5H	Dairy Farm in Indiana
NC2B	Layer Site in North Carolina	NY5H	Dairy Farm in New York State
IN3B	Finisher Swine Farm in Indiana	WA5H	Dairy Farm in Washington State
NC3B	Finisher Swine Farm in North Carolina	WI5H	Dairy Farm in Wisconsin

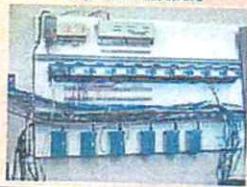
These SMP's provided the roadmap for setting up each site.



### Gas Sampling and Data Acquisition Systems



Bank of data acquisition hardware



### Equipment/DAC/Cylinders Installation



Packing trailer



### Raceway Installation

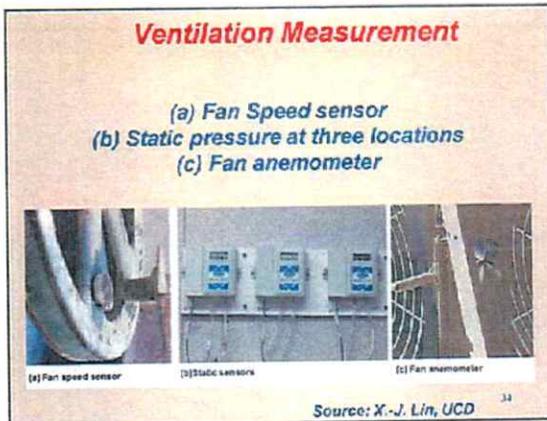
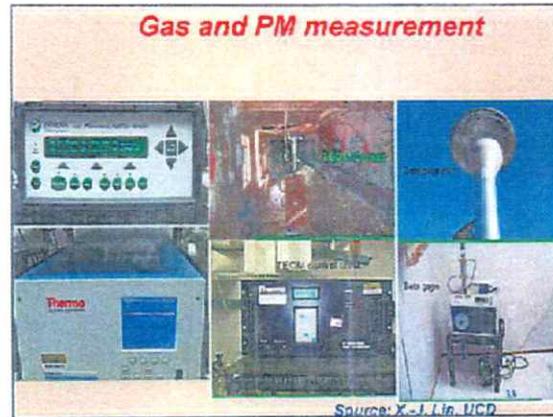


Raceway is ready

### Emission Measurement Equipment



Source: X.-J. Lin, UCD

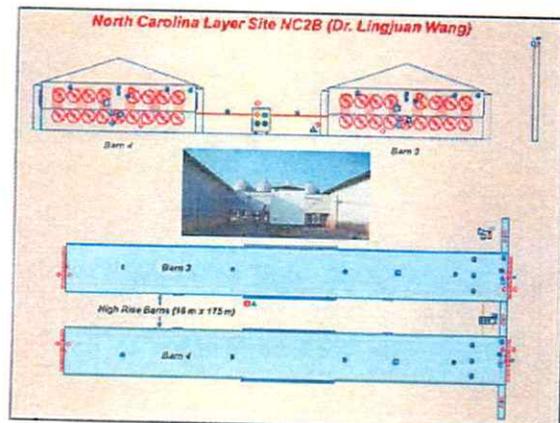
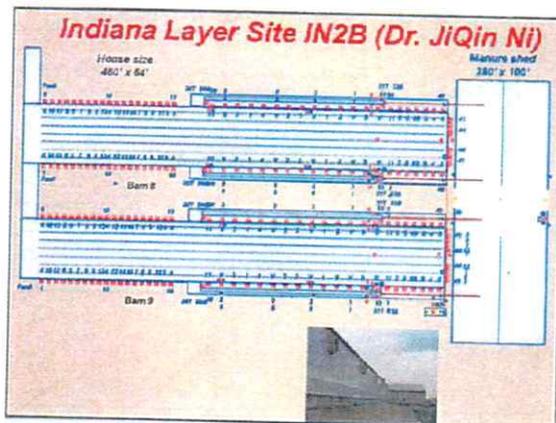
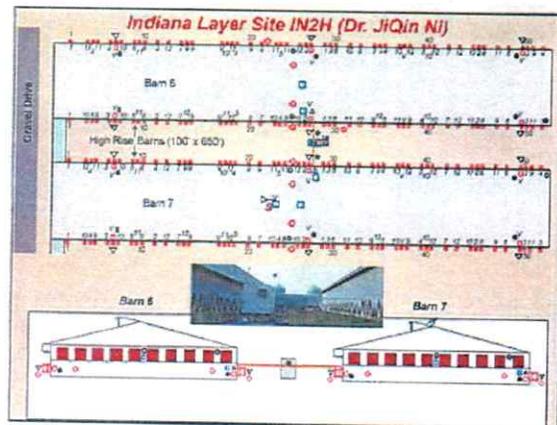
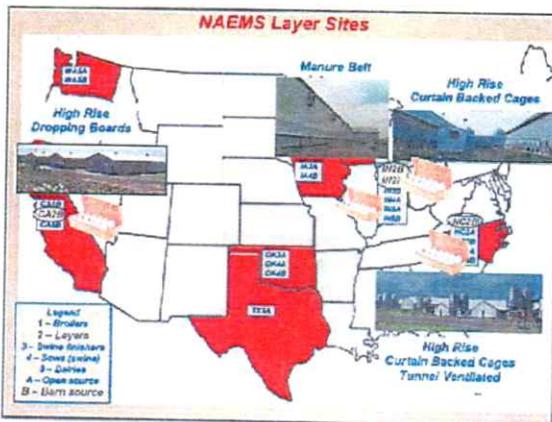
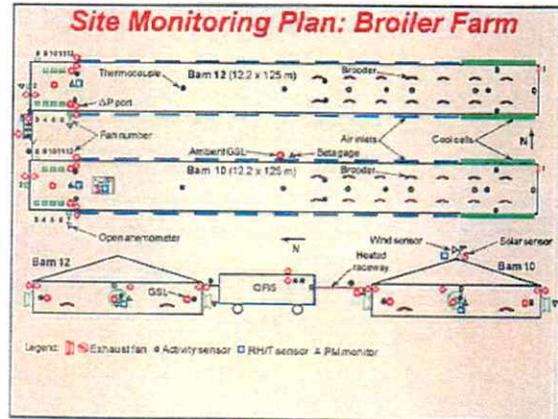
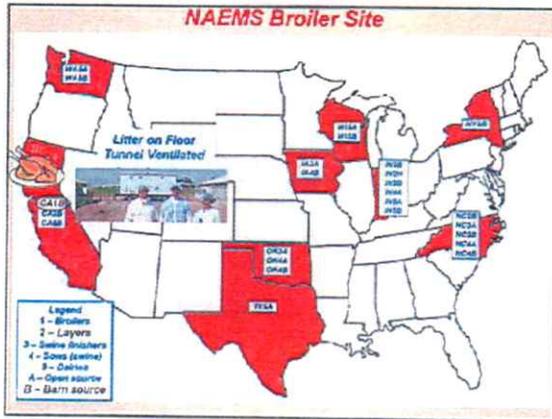


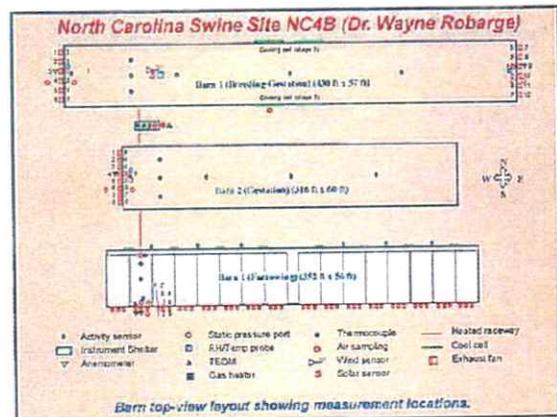
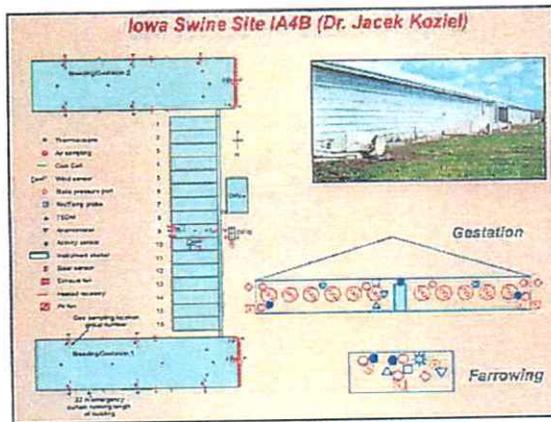
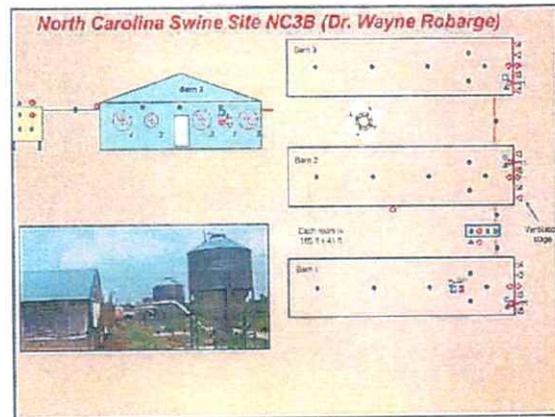
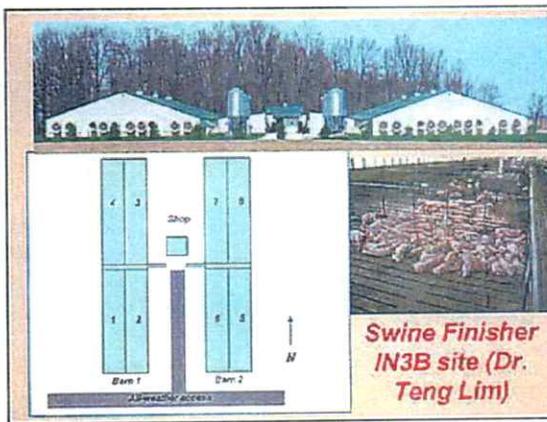
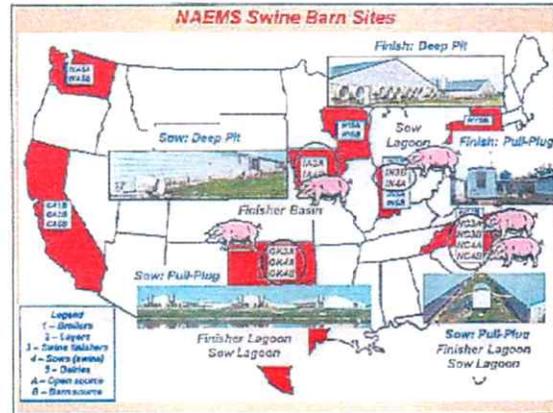
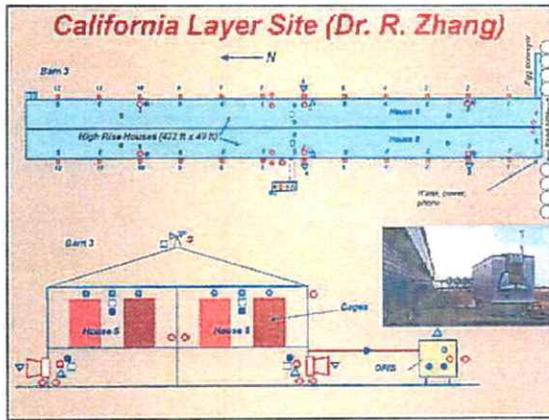
### Site Setup and Monitoring Periods

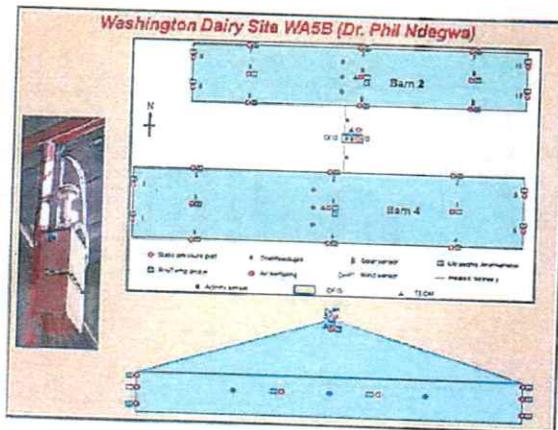
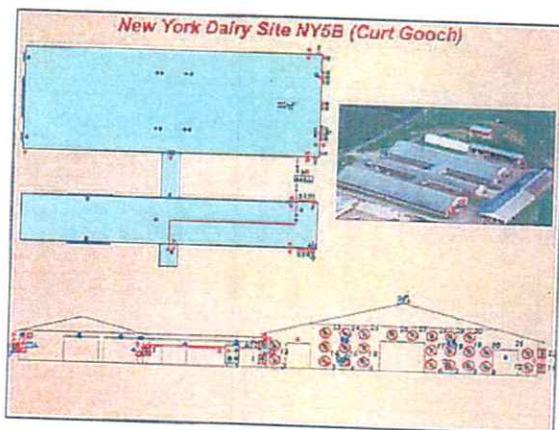
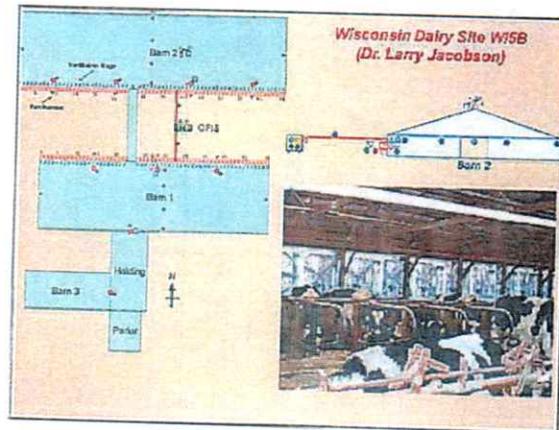
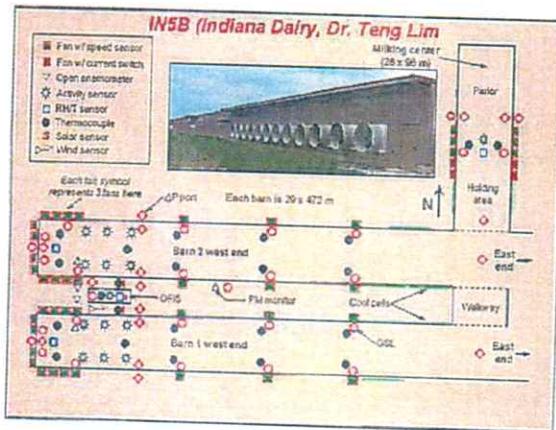
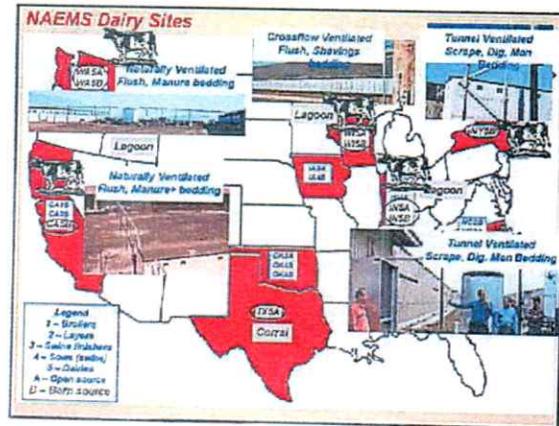
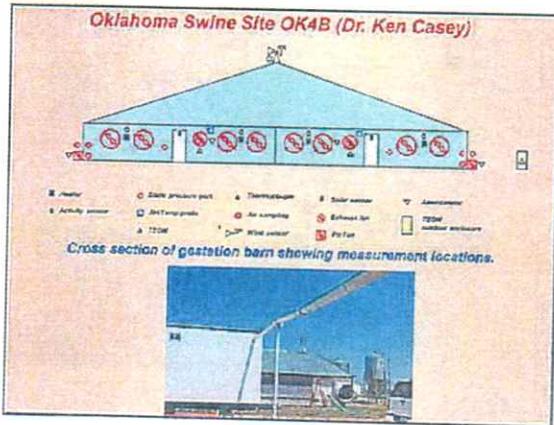
	Site	Day 1	Days to start	Monitoring Period
<b>Broilers</b>	CA1B	9/27/07	121	755
	CA2B	13/17/07	114	745
<b>Layers</b>	IN2B	1/1/08	235	730
	IN2H	8/1/07	41	730
	NC2B	9/25/07	125	736
<b>Swine</b>	IN3B	7/14/07	127	741
	NC3B	12/4/07	102	771
	NC4B	12/15/07	135	731
	IA4B	7/19/07	79	776
	OK4B	7/19/07	50	731
<b>Dairy</b>	CA5B	9/26/07	118	859
	IN5B	9/12/07	125	731
	NY5B	10/23/07	145	731
	WA5B	9/28/07	105	730
	WI5B	9/12/07	119	760
<b>Average</b>	9/21/07	116	752	
<b>Minimum</b>	8/1/07	41	730	
<b>Maximum</b>	1/1/08	235	859	

- ### NAEMS Constraints and Limitations
- > Budget
  - > Producer participation in ACA
  - > Producer collaboration
  - > Proximity to university
  - > Long set-up time
  - > Ventilation method
  - > Data complexity
  - > Real-time VOC

- ### Monitored Barn Sizes
- > Freestall barns (9): 275-800 cows
  - > Layer houses (8): 38K-250K hens
  - > Finishing barns (7): 880 - 1000 hogs
  - > Sow farms (3): 2000 - 2800 sows
  - > Broiler houses (2): 21,000 chickens

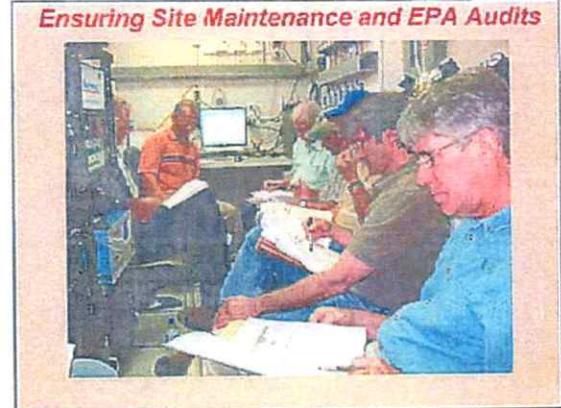






### Challenges "Along the Way"

Failures of OFIS HVAC, PC, analyzers	Mice damage to cables
Failures of TEOM Temp sensors, batteries	Faulty DIY TEOM cables
Storms: power outage, lightning, snow, etc.	Voltage fluctuations and electronic noise
Farm vehicle damaged equipment	Changes in farm management
Barn evacuations due to disease	Failure of fans and ventilation system
Changes in fan control strategy by farm	Fan maintenance affecting airflows
Overflowing pits	Wildfire smoke



### Data Completeness

Site	NH <sub>3</sub>	H <sub>2</sub> S	PM10	PM2.5	TSP
CA1B	457	591	364	48	38
IN2B	626	636	353	28	34
IN2H	518	363	407	13	19
NC2B	613	638	447	27	53
CA2B	593	623	489	41	34
IN3B	347	452	275	26	26
NC3B	496	498	440	42	58
IA4B	447	474	367	42	44
OK4B	588	595	454	32	76
NC4B	424	462	251	16	32
IN5B	428	480	358	29	72
WI5B	543	577	381	49	79
NY5B	403	573	450	55	58
WA5B	111	110	432	37	45
CA5B	207	241	486	51	65
Average	454	488	397	36	49
Target	548	548	458	21	66
100%	730	730	611	28	91

