Biofilter performance in ammonia mitigation

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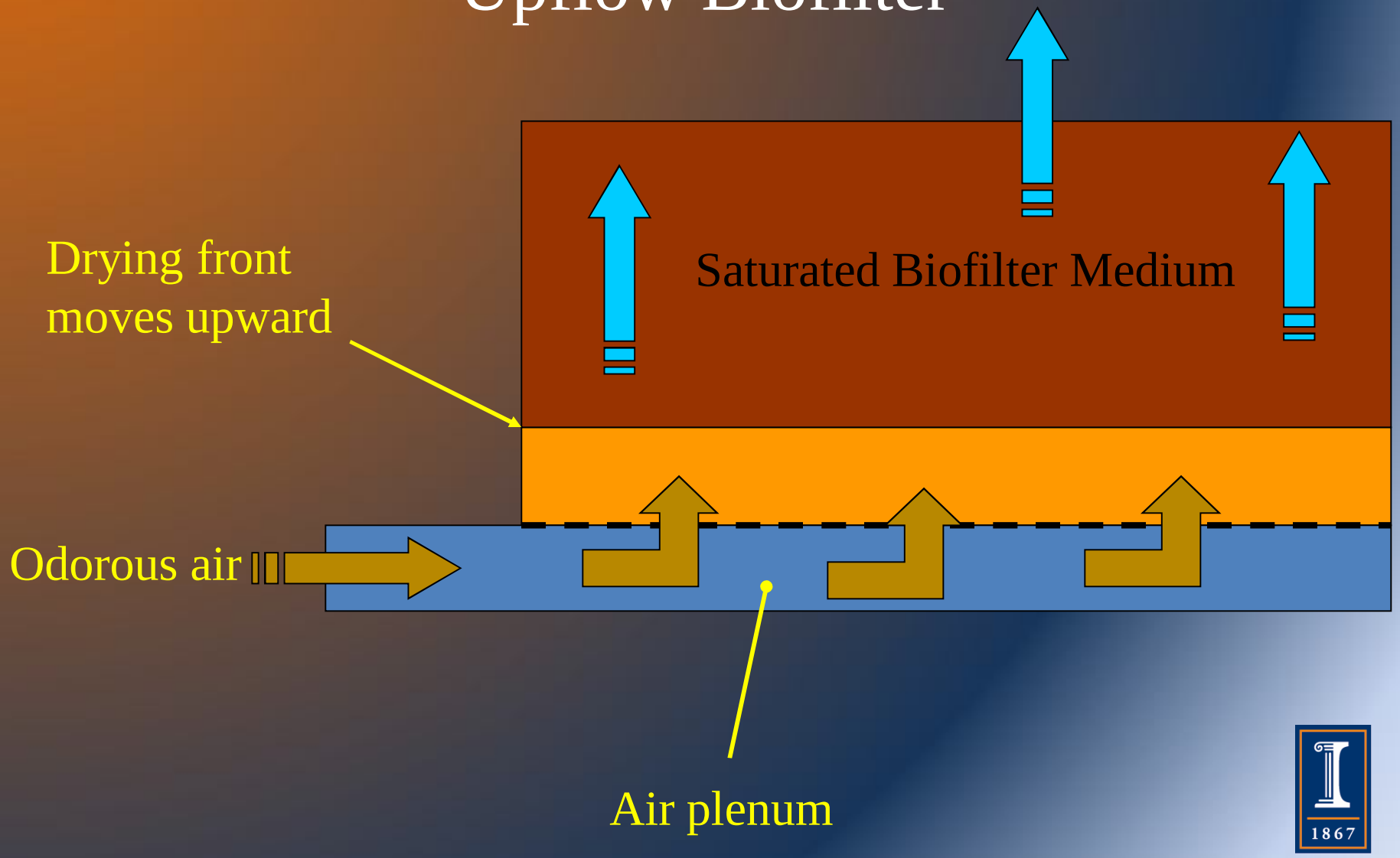
Topics for today

- Part I: Intro—what's a biofilter all about?
  - What we know, and don't know, about ammonia mitigation in biofilters
  - Our research—what else happens during biofiltration?
- Part II: Our biofilters, our design philosophy
  - What's next
  - Our partners

What is a Biofilter?

- Layer of organic material, filtering air contaminated with pollutants
  - Contains/supports a microbial population
  - Receives odorous air forced through it by fan(s)
  - Microbes convert compounds in the odorous air to other products, some of which stay in the biofilter, some are non-odorous

Air Movement in an Upflow Biofilter



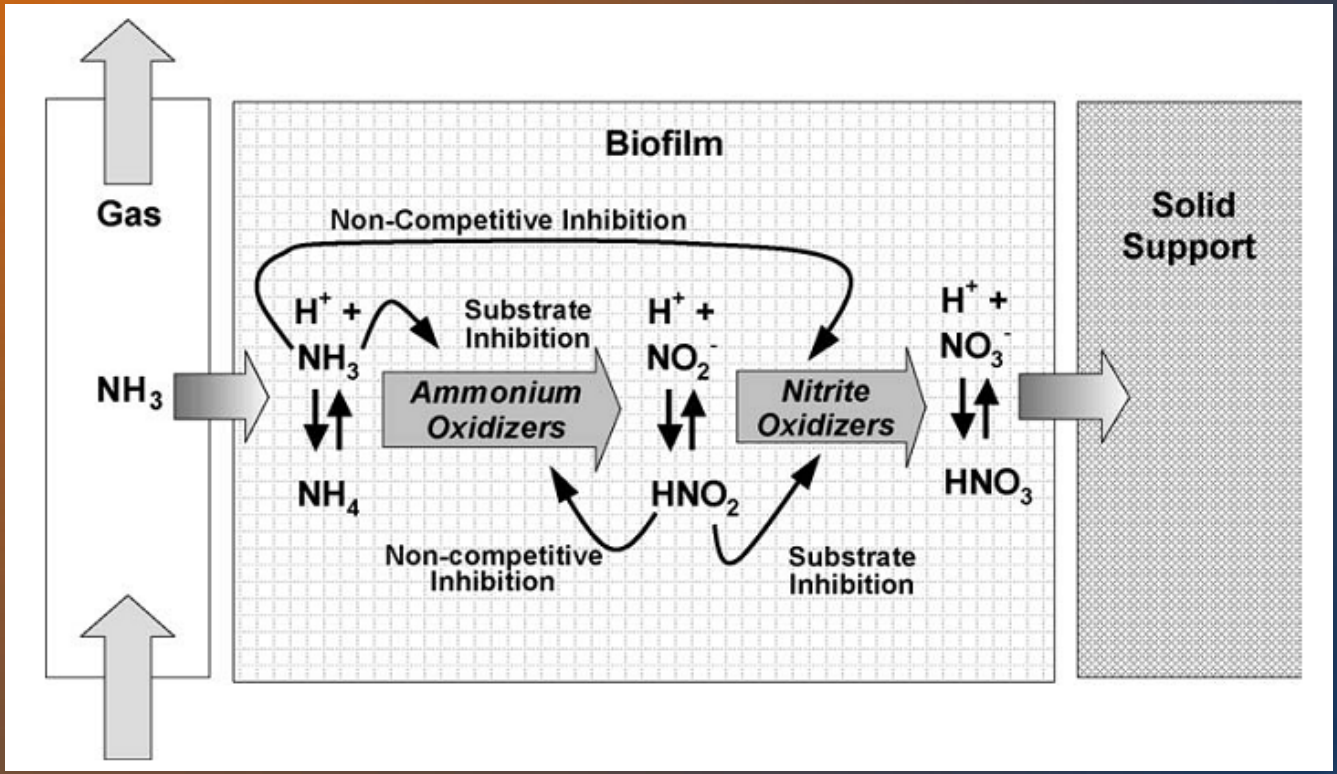
One low-cost biofilter format: IA study

Photos: Hoff et al. 2009.

Field research results

- Hoff et al. 2009. 73% reduction of ammonia in pit fan exhaust, with a 3.25 second calculated EBRT with a 25 cm media depth.
- Averaging about 10 ppm input, always < 20 ppm

Nitrification in a Biofilter



Proposed by G. Baquerizo et al. / Chemical Engineering Journal 113 (2005) 205–214

Step 1: Absorption/adsorption

Step 2: Nitrification

Nitrosomonas $NH_3 + O_2 \rightarrow NO_2^- + 3H^+ + 2e^-$ (1)

Nitrobacter $NO_2^- + H_2O \rightarrow NO_3^- + 2H^+ + 2e^-$ (2)

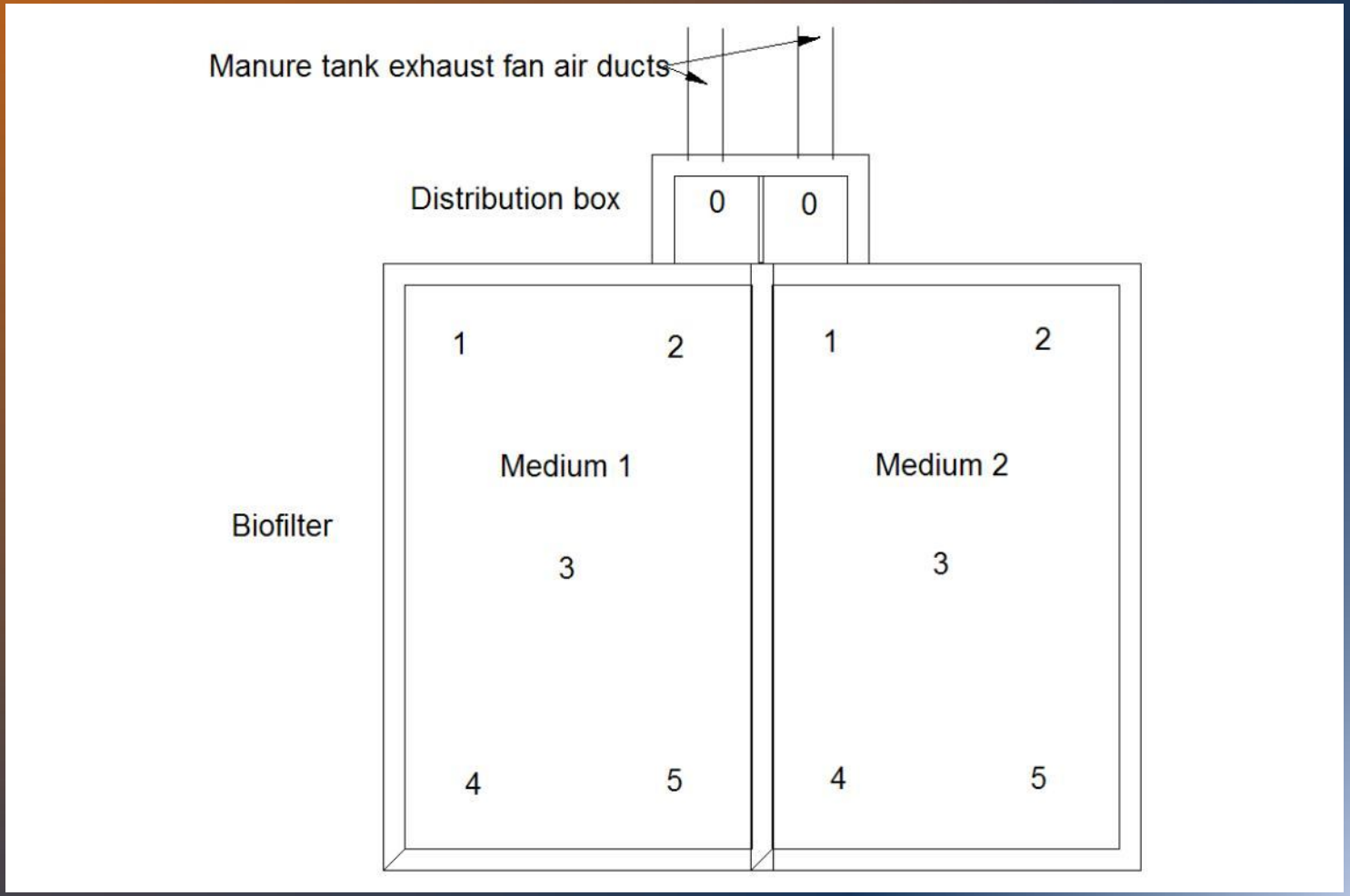
In-ground manure tank headspace vent odor control: an Illinois field study

Biofilters reduce air emissions

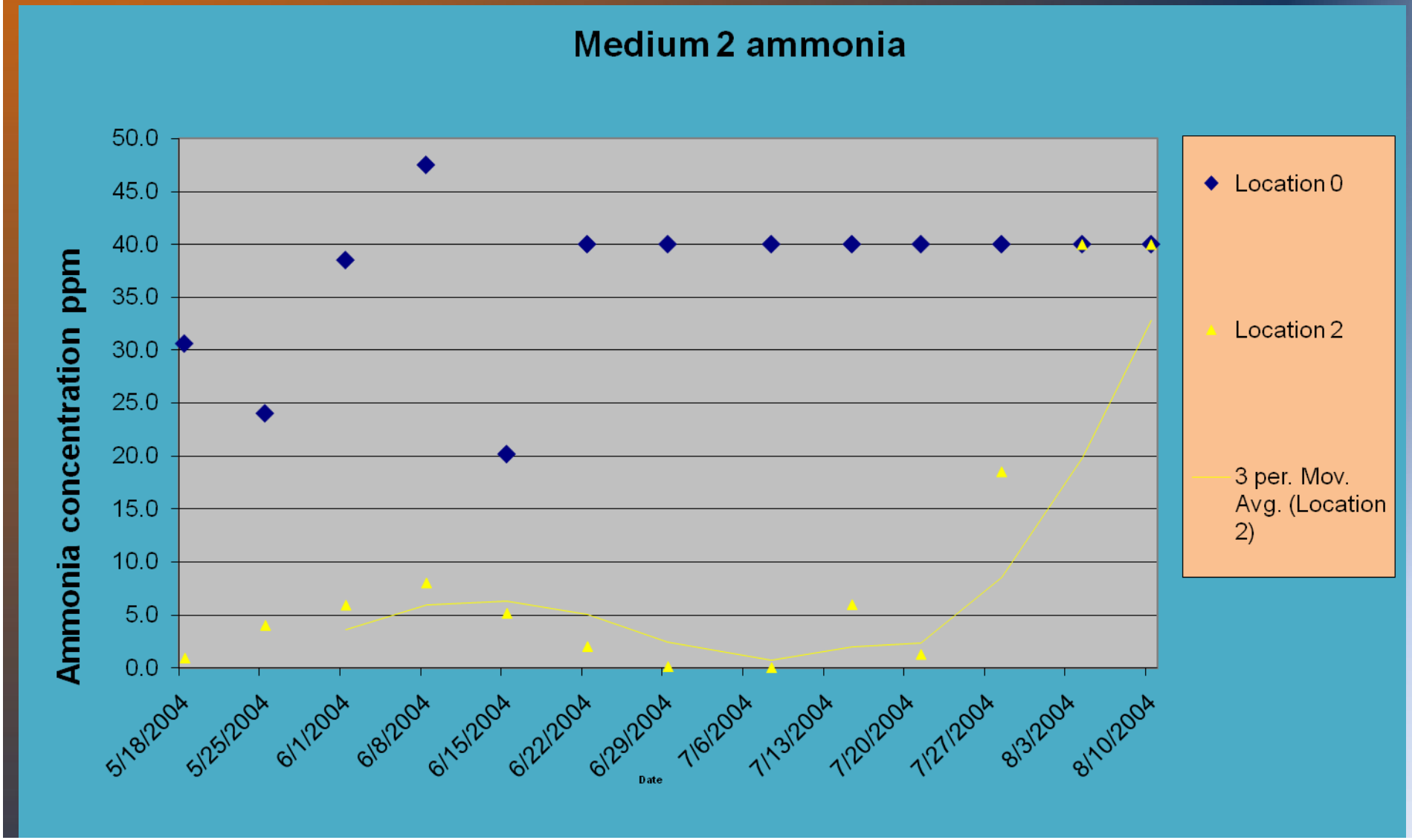
- Reduce ammonia about 60%
- Reduce hydrogen sulfide about 80%
- Cut odor 60-80%
- BUT without good management, N_2O emissions† can be produced

†N_2O is a "greenhouse gas"

Biofilter performance field tests: Sampling points



Interpreting Field Results: a messy business



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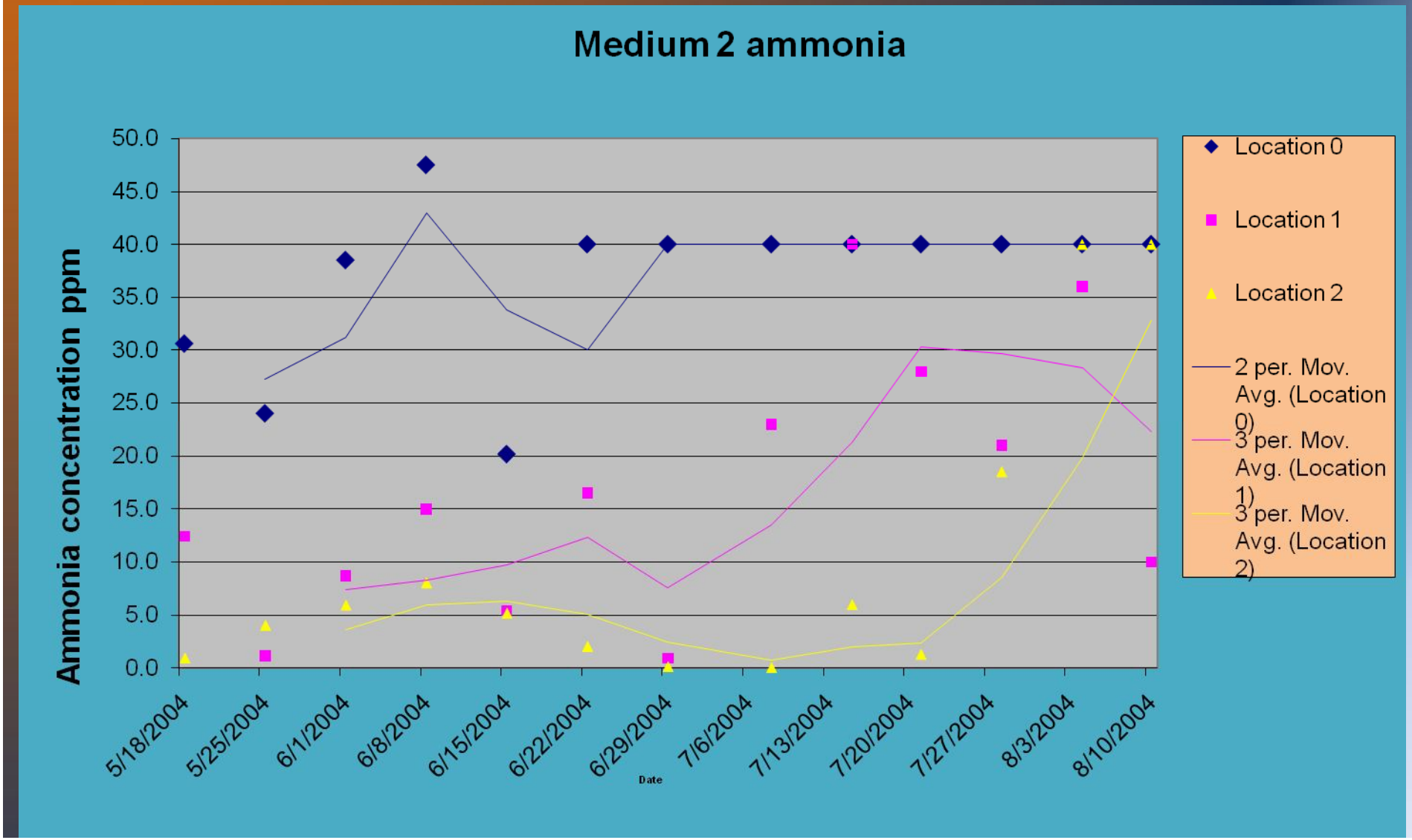

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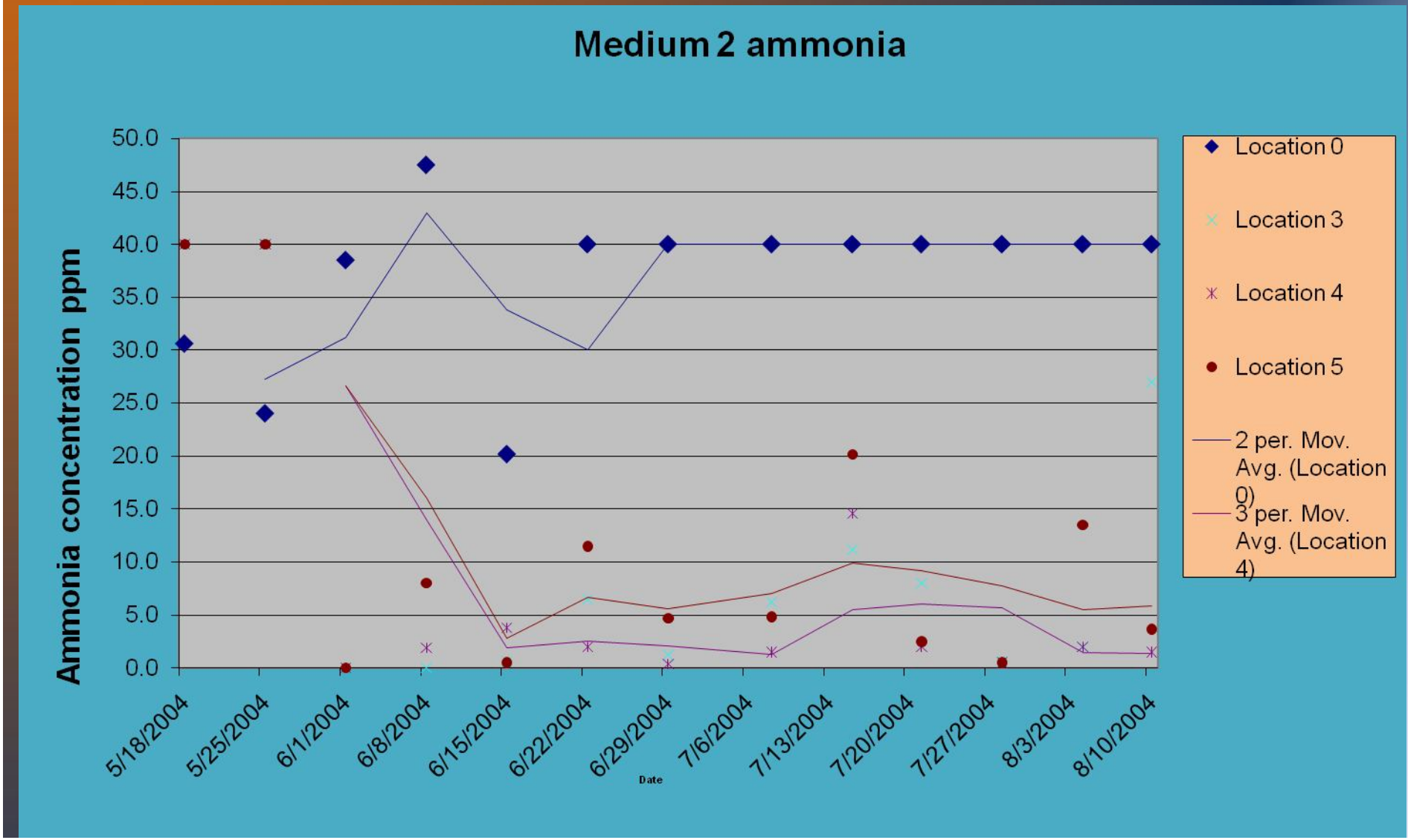

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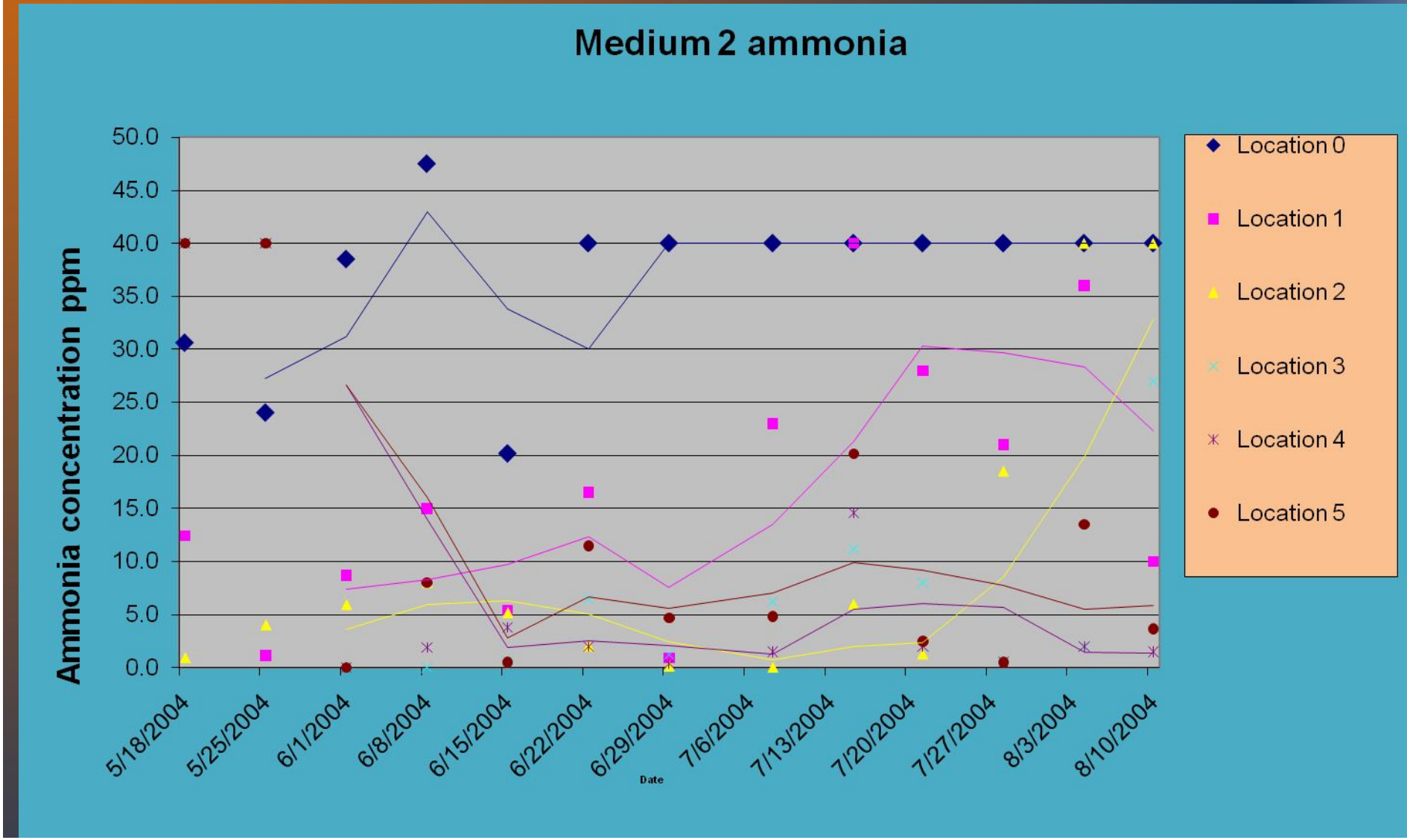


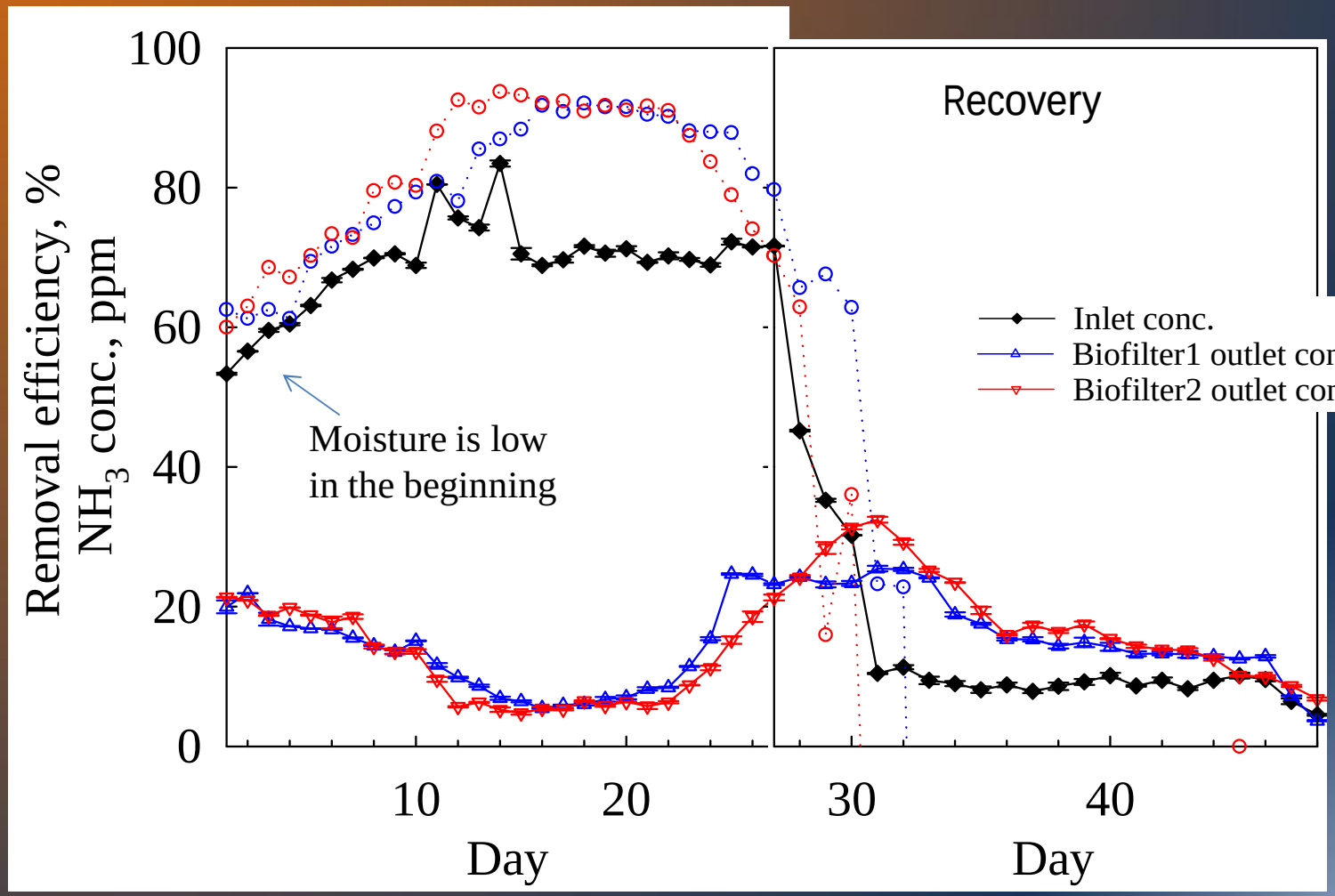
The whole picture on ammonia attenuation via biofilters

- Is the biofilter still, after years of research, a “black box” regarding ammonia transformation?
- Nitrogen cycle in a biofilter appears to be similar to the N cycle in soils
- Nitrate is the endpoint, and it stays in the biofilter…
- …unless there’s the occasional flush of liquid

Factors in ammonia attenuation

- Time
- Temperature
- Moisture availability for biofilm
- Concentrations of NH_4^+, NO_2^-, NO_3^- in the media that inhibit microbial processes

Ammonia Removal Performance: lab scale biofilter (IL)



Critical Elements for Further Study

- Snapshot performance measurement vs. long-term
- Can we control moisture content to attain our performance goal?
- What EBRT in the biofilter is necessary for NH_3 attenuation?
- Keeping the whole biofilter aerobic seems to be critical for avoiding production of N_2O

Biofilter container formats

- Bottom fed upflow (also industrial applications)
- Top fed upflow
- End fed sideflow
- Side fed sideflow
- Other commercial oddities

Many creative biofilter container formats

SDSU Vertical Biofilter, PSF, N. MO

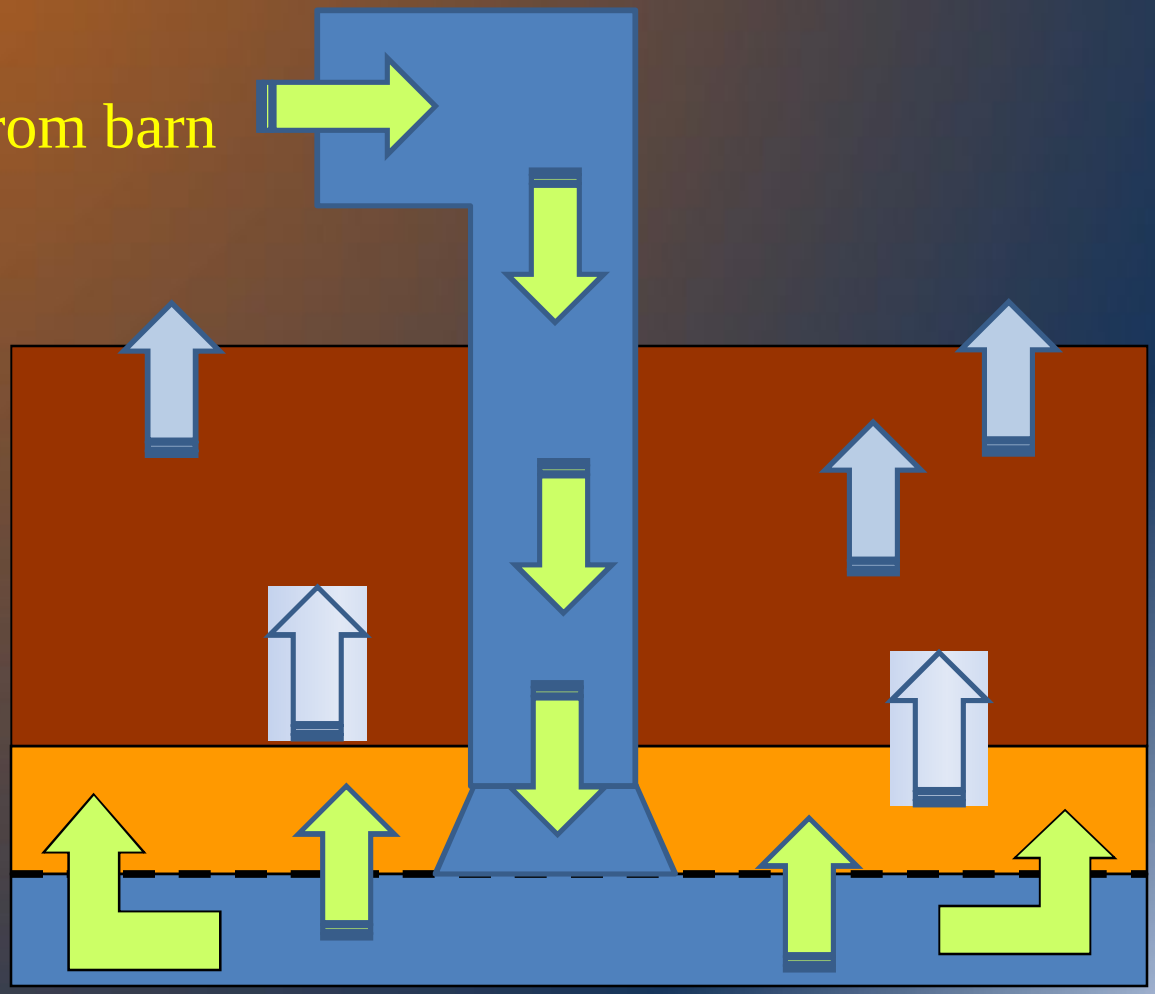
Other (commercial) formats

Odor Cell Technologies™ LLC

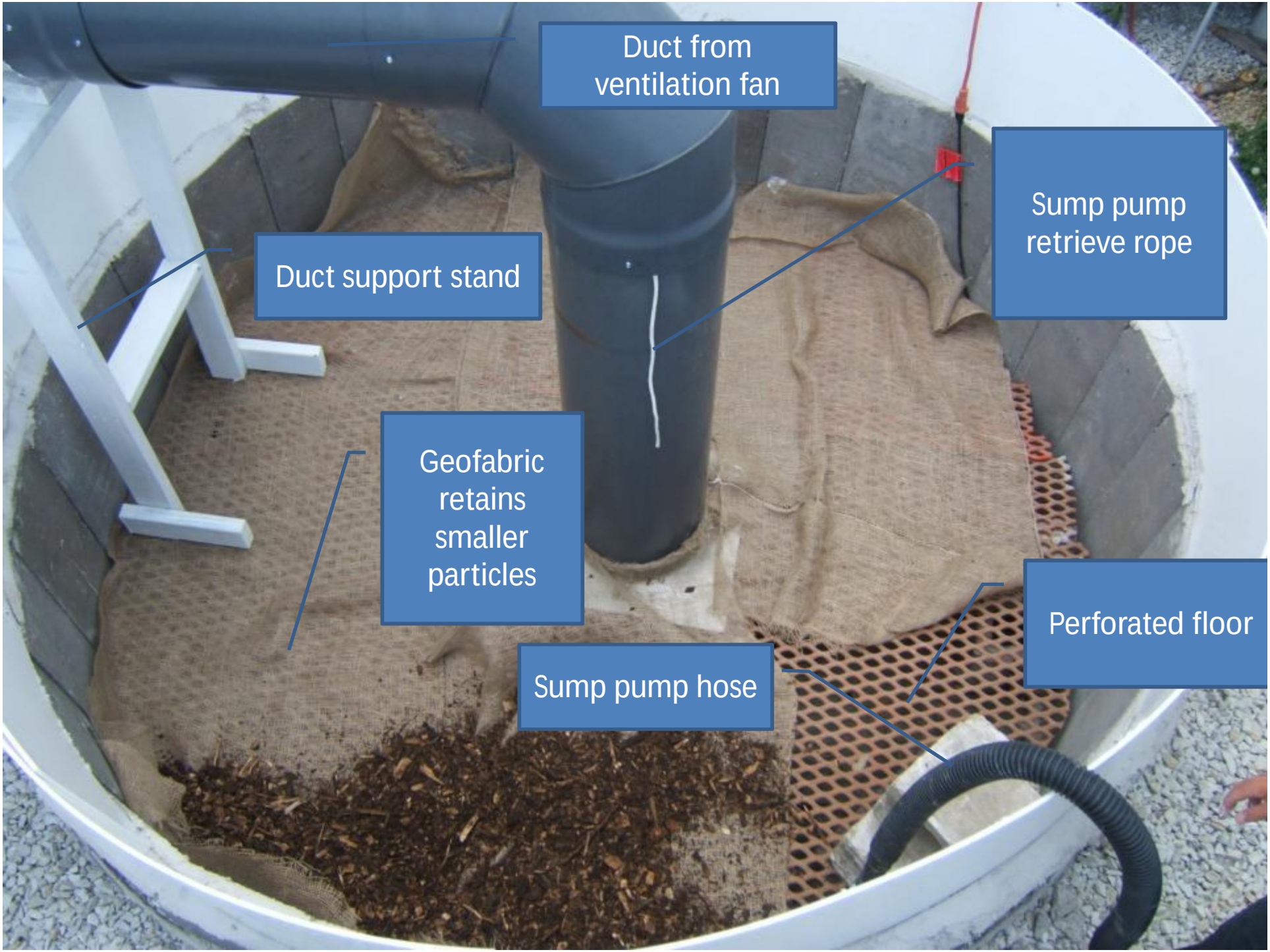
Air Movement in a Top-fed Upflow Biofilter

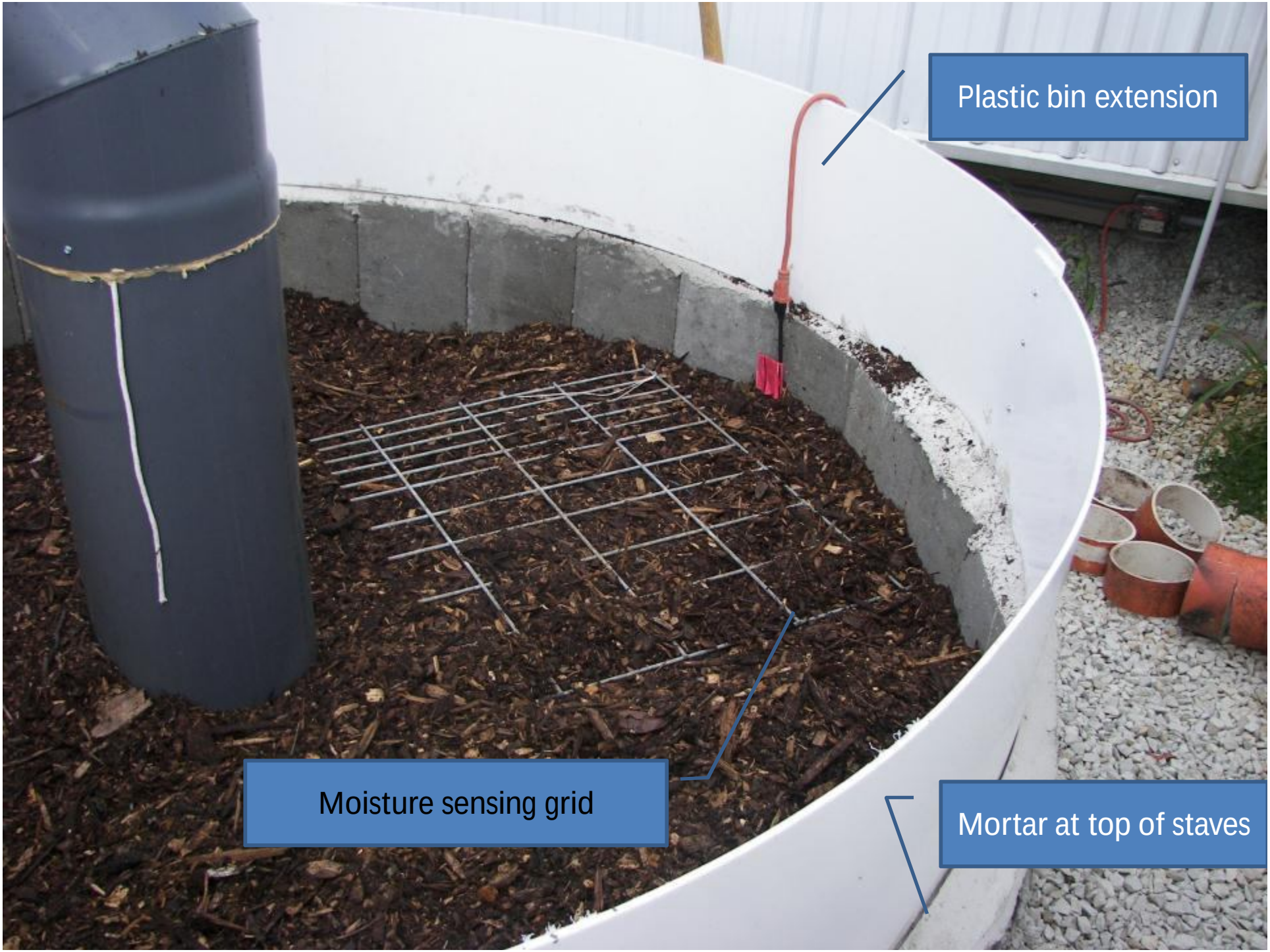
Odorous air from barn

Saturated Biofilter Medium




fan


Duct from ventilation fan
Sump pump retrieve rope
Duct support stand
Geofabric retains smaller particles
Perforated floor
Sump pump hose


Plastic bin extension
Moisture sensing grid
Mortar at top of staves

Can biofilters treat all the air from my building?

Recommendation: treat the air from the pit fans or other minimum-rate fans (Hoff et al, 2009)

Matching fan and biofilter performance

Get test data on your fans at www.bess.illinois.edu

TEST RESULTS

MULTIFAN 4E63-3PP-S3C

Test: 96300

Fan description:
24" direct drive, 0.43 kW Vostermans
4E63-3PP-S3C motor, plastic housing,
plastic shutter, guard and discharge cone

Static Pressure in. water	Speed rpm	Airflow cfm	Efficiency cfm/Watt
0.00	1666	5830	16.5
0.05	1658	5560	15.2
0.10	1648	5280	14.4
0.15	1642	4980	13.1
0.20	1635	4640	12.1
0.25	1631	4370	11.1
0.30	1626	3890	9.8

$$\Delta P_k := depth \frac{a \cdot (Q_k)^2}{\ln(1 + b_{H1} \cdot Q_k)}$$

Pressure Drop with different Flow Rates (cont.)

Media	Moisture Content, wt%	A	B	R^2
medium shreded mulch	52.14%	10025	10.46	0.9984
medium shreded mulch, *compacted*	52.14%	15687	13.19	0.9985
fine shreded hardwood mulch	54.39%	24378	7.983	0.9988
Fine shreded hardwood mulch, *compacted*	54.39%	35339	7.977	0.9995
acidified pine mulch	55.09%	15628	11.47	0.9989
Fresh chipped hardwood mulch	41.67%	23267	61.17	0.9982
Composted chipped hardwood mulch	53.45%	26240	25.94	0.9997
Leaf compost	51.42%	60739	12.50	0.9996
Leaf compost, *compacted*	51.42%	93298	11.08	0.9996
Manure compost	65.58%	112231	14.85	0.9995

Summary:
➢***Hukill and Ives Equation*** fit good for both compact and un-compacted media;
➢ A and B may closely relate to physical and chemical properties of media.

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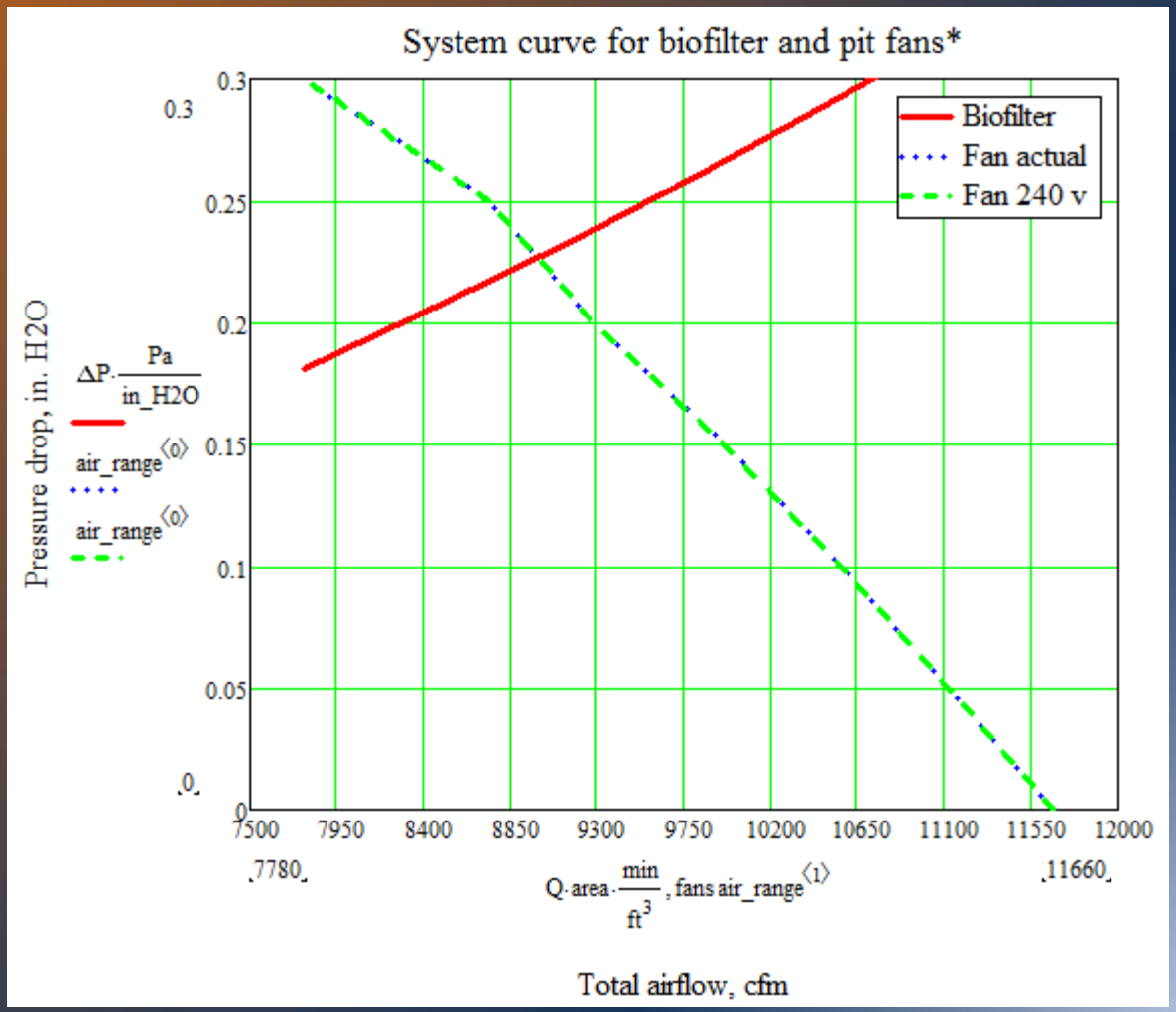
Biofilter system curve for specific biofilter media



Biofilter Management for Performance

- Moisture content of media
- Monitor leachate and its fate
- Watch pressure drop for big changes
- Empty and replace media as needed

Biofilter moisture addition methods

- Gas phase humidification systems
- Sprinklers and sprayers
- Soaker hose
- Continuous trickling biofilters

Big challenge: Biofilter moisture instrumentation & control systems

- Manual (put your hand in and feel a sample)
- Pointwise (see literature on soil moisture measuring instruments)
- Large-format capacitor method

Resources

- Hoff, S.J., J. D. Harmon, L. Chen, K. A. Janni, D. R. Schmidt, R. E. Nicolai, L. D. Jacobson. 2009. Partial Biofiltration of Exhaust Air from a Hybrid Ventilated Deep-Pit Swine Finisher Barn. Applied Engineering in Agriculture. 25(2): 269-280.
- Melse, R.W., N. W. M. Ogink. 2005. Air scrubbing techniques for ammonia and odor reduction at livestock operations: review of on-farm research in the Netherlands. Trans. ASAE, Vol. 48(6): 2303−2313
- Del Nero Maia, G.; Day V, G.B.; Gates, R.S.; Taraba, J.L.; Sales, G.T.; Lovanh, N. 2009. Ammonia removal and nitrous oxide production in gas-phase compost biofilters. Proc., I Simpósio Internacional sobre Gerenciamento de Resíduos de Animais, Emissão de Gases Associados a Produção Animal e ao Manejo de Dejetos. 11 a 13 de Março de 2009 – Florianópolis, SC – Brasil.

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  - Illinois Environmental Protection Agency

Summary

- Biofilters are pretty good at removing odor
- They also can remove some ammonia most of the time
- But if they produce nitrous oxide, which is sure to be regulated, we may have lost ground
- How do we control performance and balance risk?