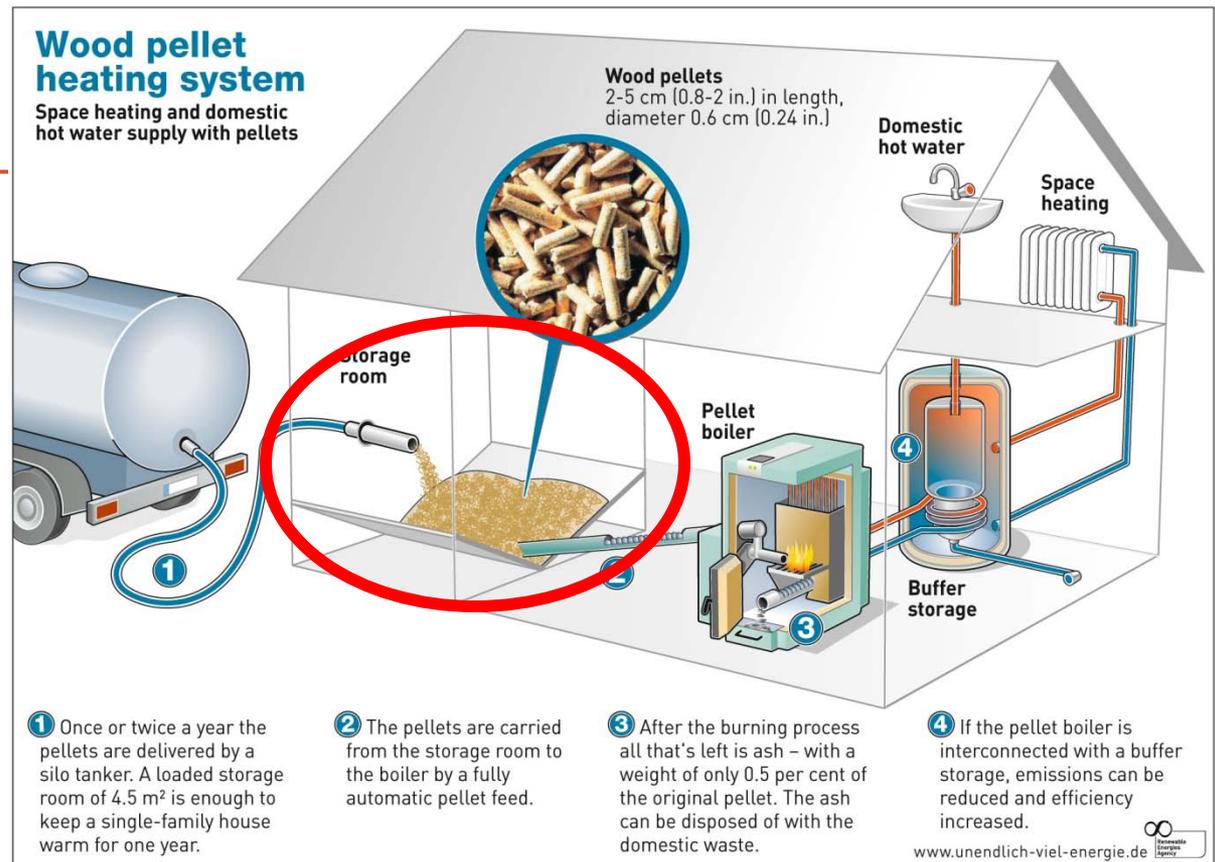


OFF-GAS EMISSION KINETICS OF CO AND VOCS FROM WOOD PELLET STORAGE.

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Jason Herrington
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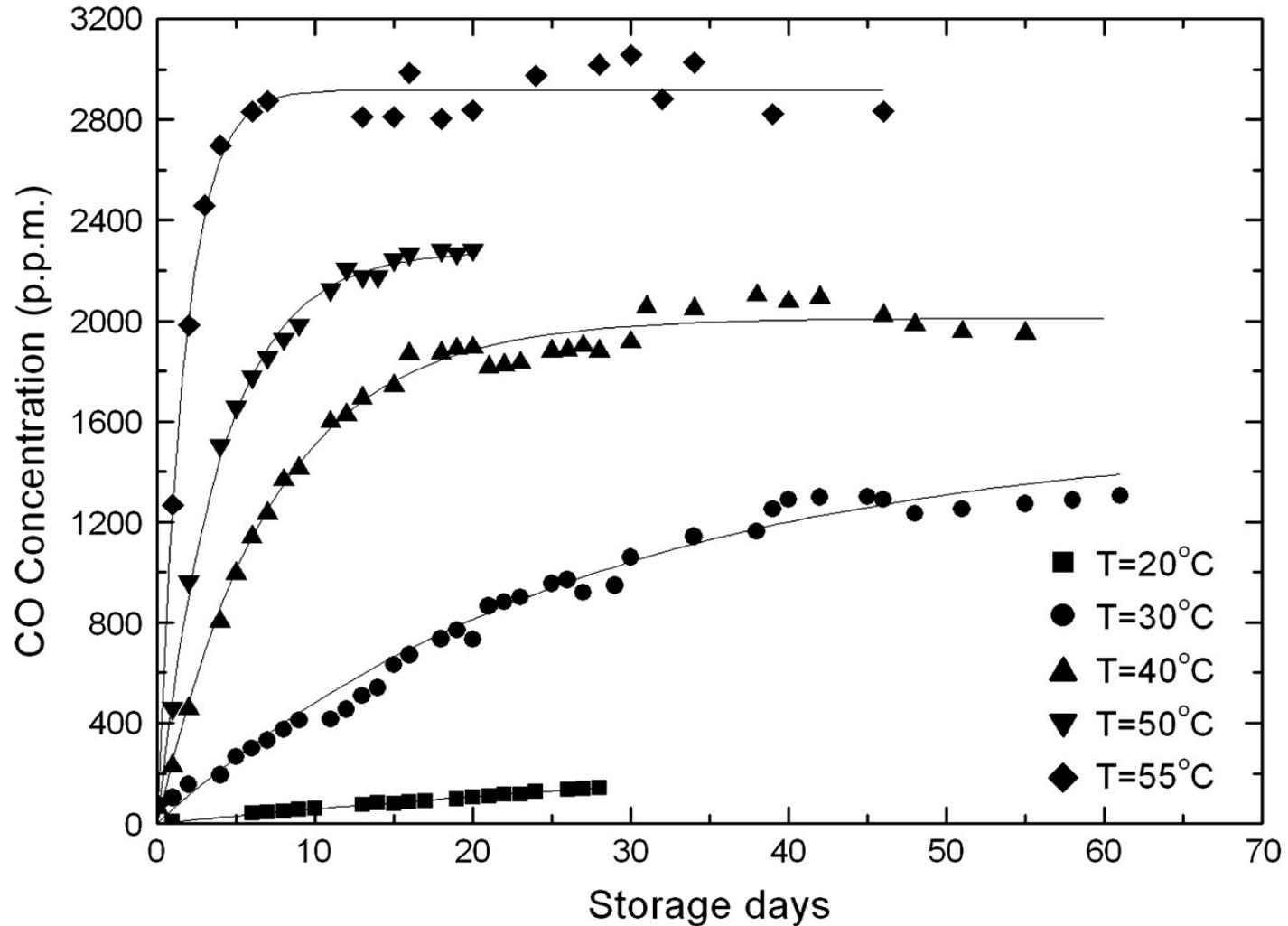
Outline

- **Introduction** - The potential health impacts from the emissions of biomass fuels, including wood pellets, during storage and transportation has not been fully studied.
 - Concerns associated with bulk storage of Wood Pellets
- **Carbon monoxide**
 - Hazardous/Health Effects
 - Emission rates
 - Concentrations in Storage bins
- **Emission of Volatile Organic Compounds (VOC) from bulk Storage Pellets**
 - Are they (VOC) really a concern?
 - Emissions rates
 - Concentrations
- **Confined Space entry considerations**
 - Hazards
 - OSHA regulations
 - Guidelines for private residences
- **Conclusions**

Introduction

- Svedberg et al. (2004) Emission of Hexanal and Carbon Monoxide from Storage of Wood Pellets, a Potential Occupational and Domestic Health Hazard
- Kuang et al. (2008) Characterization and Kinetics Study of Off-Gas Emissions from Stored Wood Pellets.
- Gauthier et al. (2012) Lethal Carbon Monoxide Poisoning in Wood Pellet Storerooms—Two Cases and a Review of the Literature
- Fan and Bi (2012) Kinetic model for wood pellet emissions.

CO concentrations in the 45-l containers as a function of storage time at different storage temperatures using BC wood pellets.

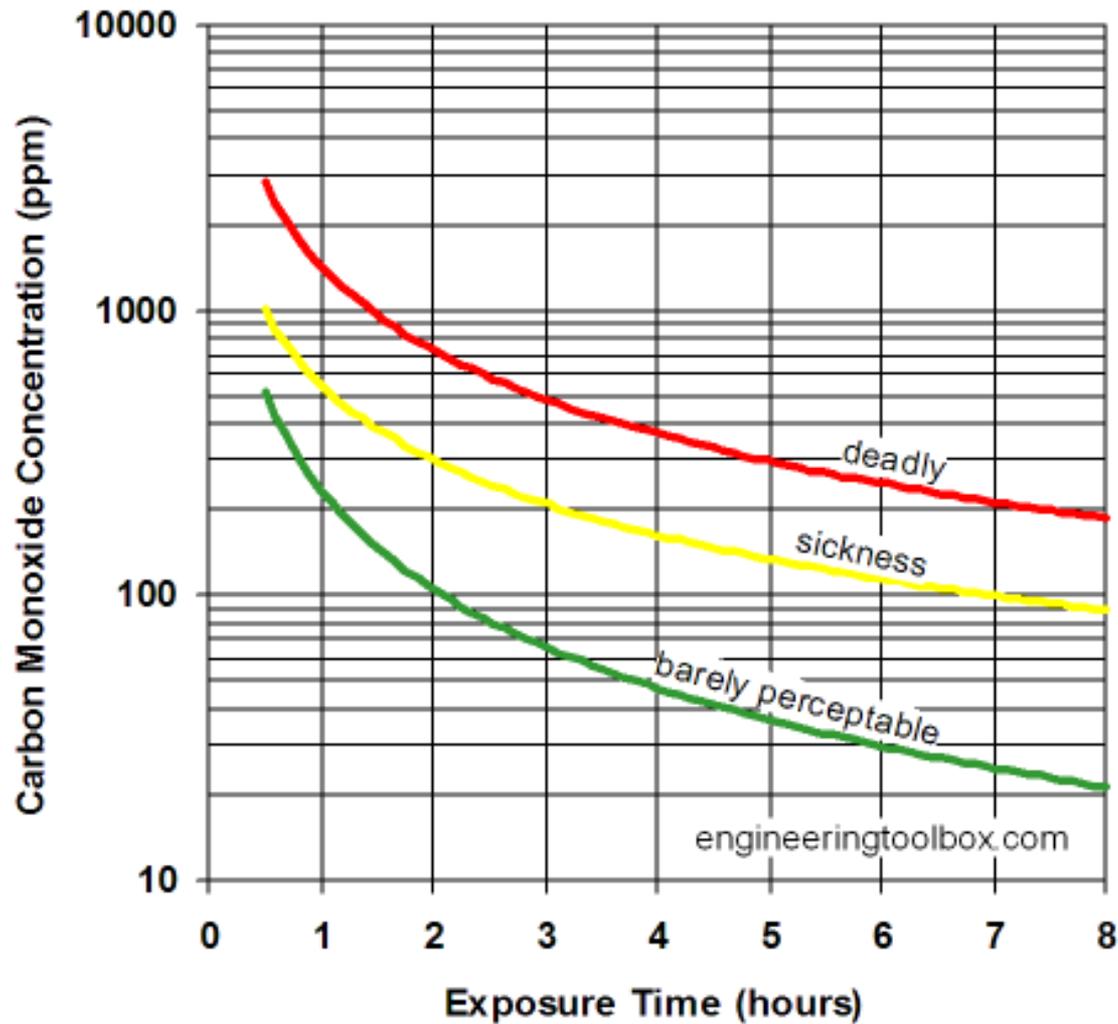


Kuang X et al. Ann Occup Hyg 2008;52:675-683

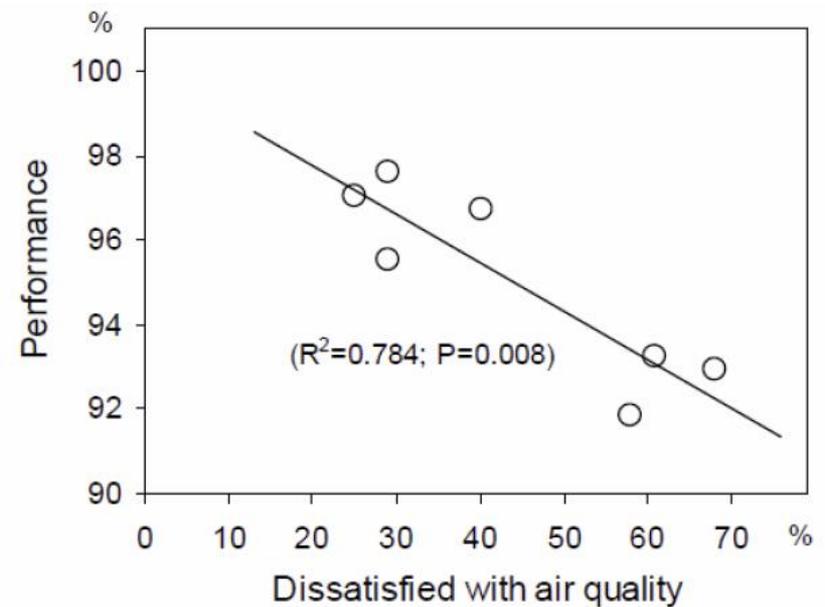
Carbon Monoxide Exposure Guidelines

Concentration of CO in the air (ppm)	Inhalation Time	Toxic Symptoms
9	Short term exposure	ASHRAE recommended maximum allowable concentration in living area.
35	8 hours	The maximum exposure allowed by OSHA in the workplace over an eight hour period.
200	2-3 hours	Slight headache, tiredness, fatigue, nausea and dizziness.
400	1-2 hours	Serious headache-other symptoms intensify. Life threatening after 3 hours.
800	45 minutes	Dizziness, nausea and convulsions. Unconscious within 2 hours. Death after 2-3 hours.
1,600	20 minutes	Headache, dizziness and nausea. Death within 1 hour.
3,200	5-10 minutes	Headache, dizziness, nausea. Death within 1 hour.
6,400	1-2 minutes	Headache, dizziness, nausea. Death within 25-30 minutes.
12,800	1-3 minutes	Death within 1-3 minutes

CO Exposure vs Time



VOCs - Health, Performance and Comfort

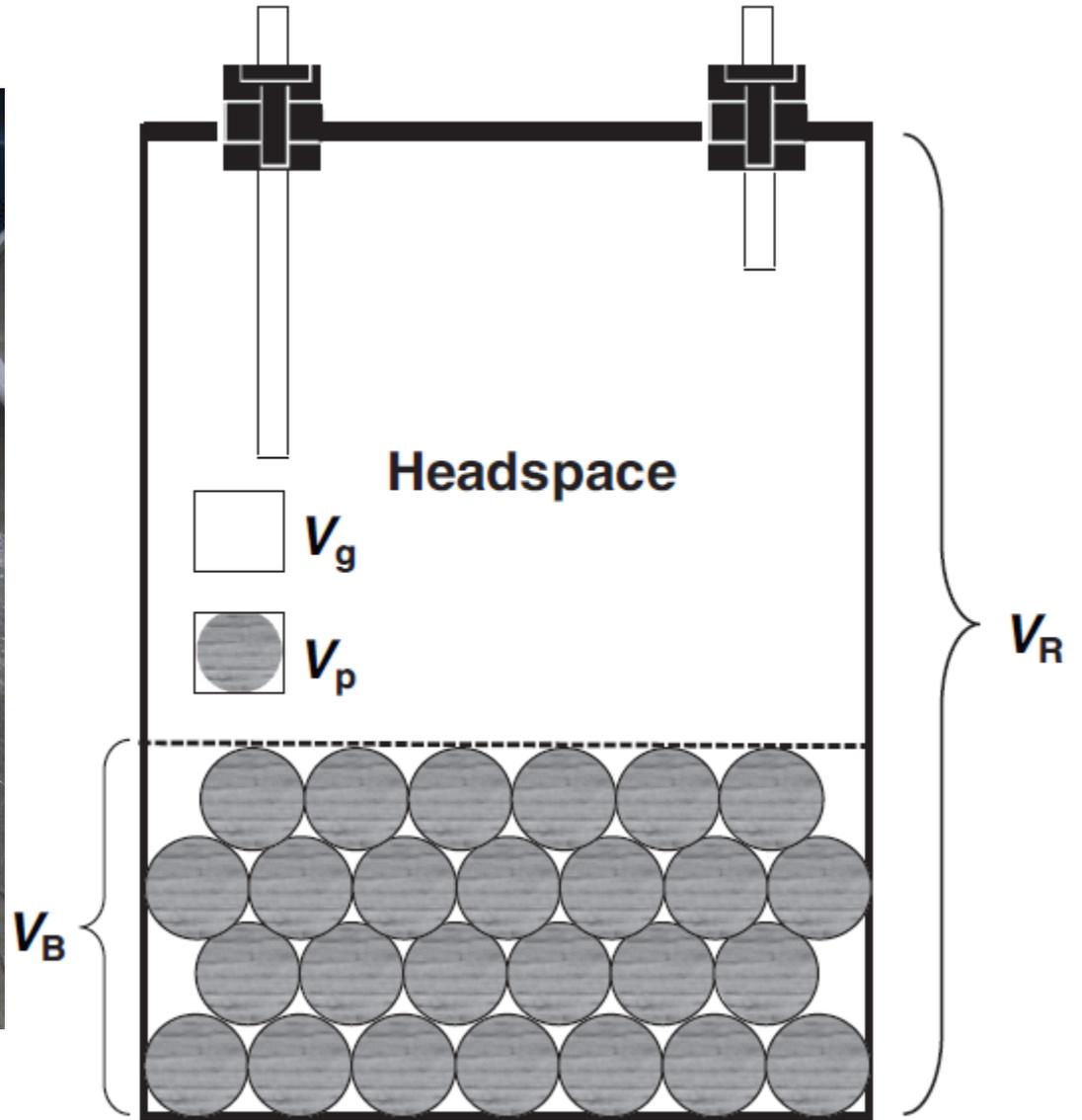


Health Effects of VOCs in Indoor Environments

- Anywhere from 50 to 300 different individual VOCs, each present in a microgram per cubic meter concentration range (mg/m³) may combined to cause a variety of health effects.
- Adverse health responses attributed to VOCs in non-industrial indoor environments include: mucous membrane irritation, systemic effects such as fatigue and difficulty concentrating, and toxic effects such as carcinogenicity.
- A growing body of research linking domestic exposure to VOCs to adverse respiratory health outcomes in children.
 - (Ref Weschler, 2009, Franklin, 2007)

The aim of our study:

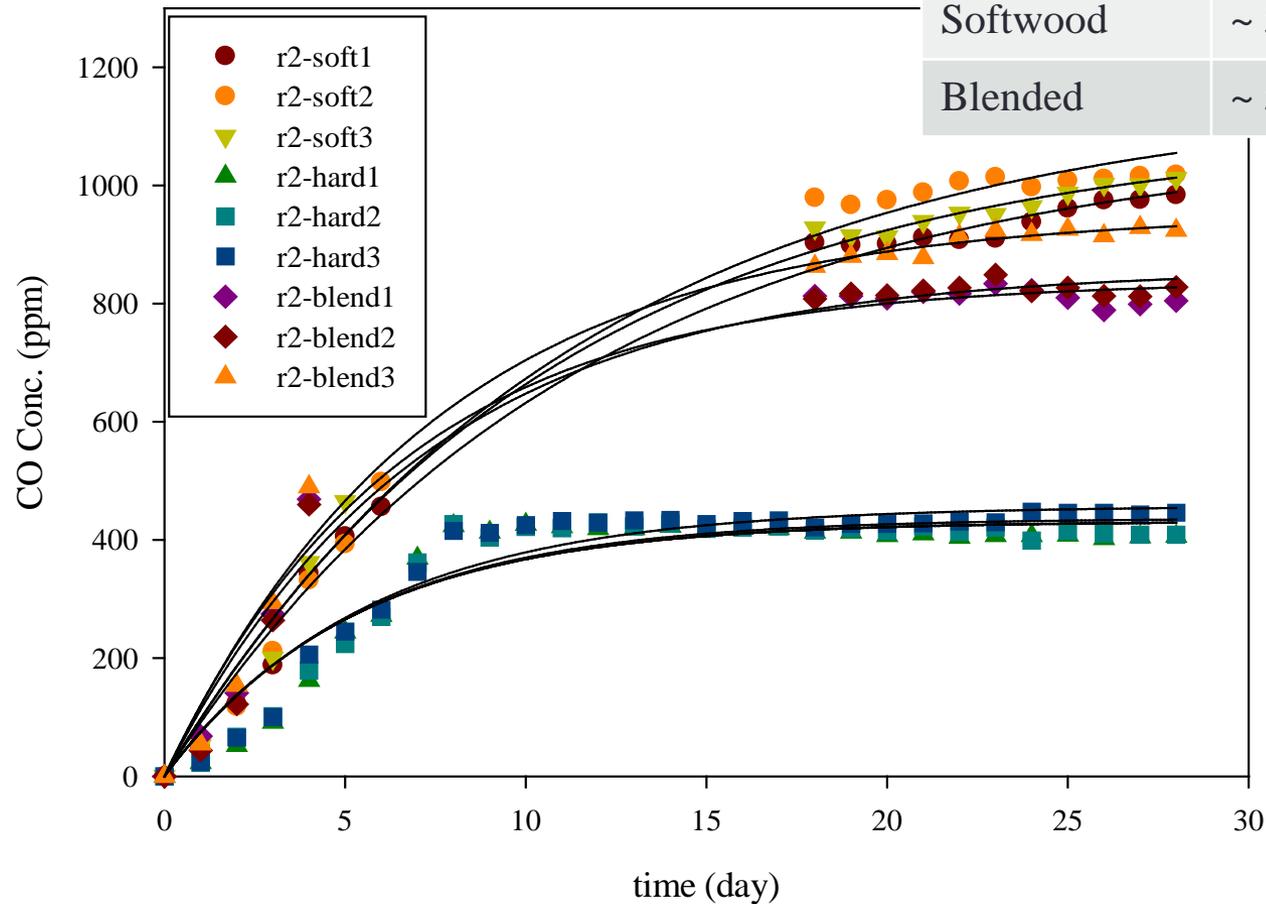
- To better understand the emission rates of CO and VOCs from hardwood, softwood, and a blended mixture of pellets in order to provide a safer living environment and storage room design.
- **Objectives:**
 - Identify specific volatile organic compounds (VOCs) being off-gassed from wood pellets over 30 day period in sealed barrels.
 - Determine concentrations of CO and VOCs in barrel headspace by hardwood, softwood, and a mixed blend of wood pellets.
 - Understand the variability in emission rates between hardwood, softwood, and blended pellets.
 - Generate kinetic model in order to predict the rate at which CO and VOCs accumulate in a confined space with no or limited ventilation.
 - Conduct field measurements to validate lab studies



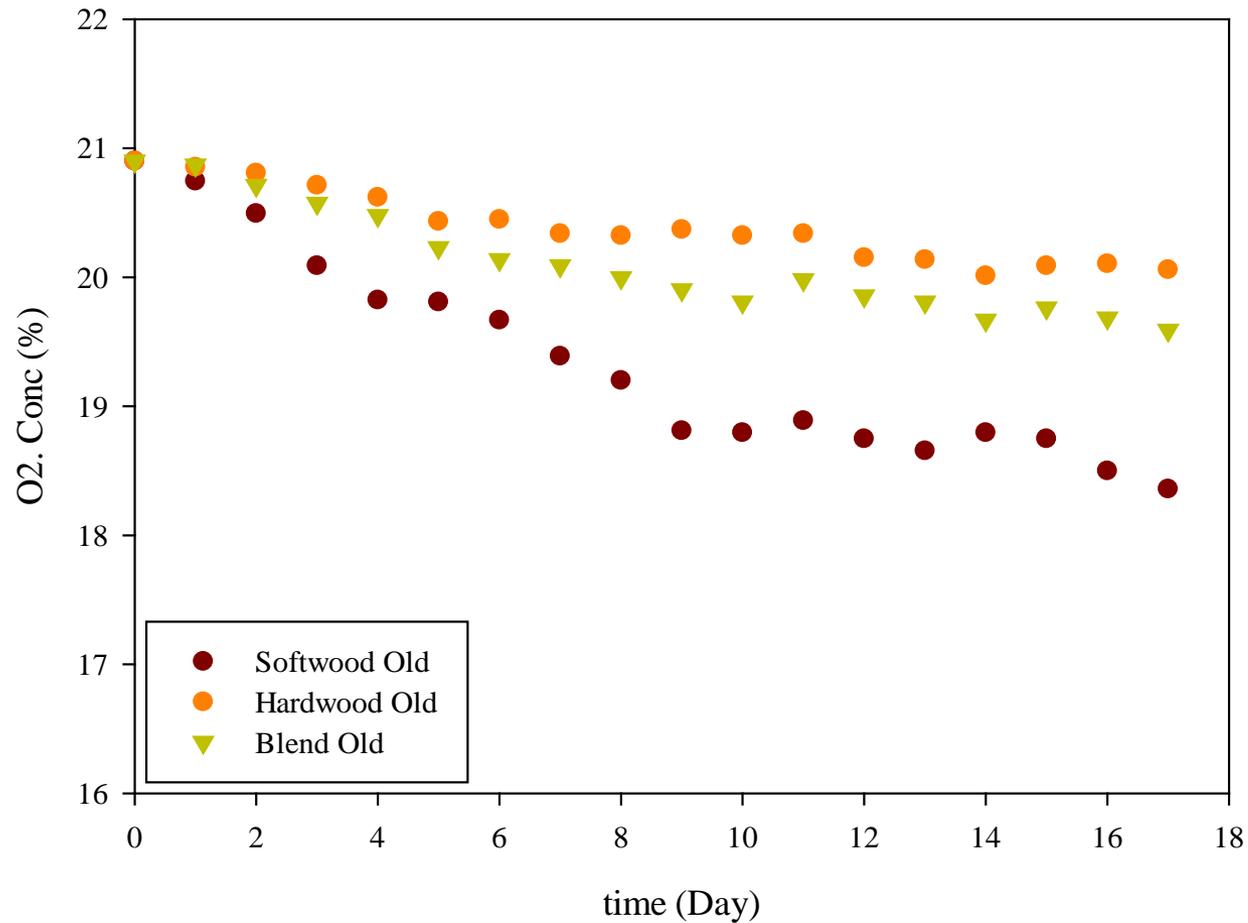
*21 gal steel barrels, closed system

CO concentration curves - Round 2

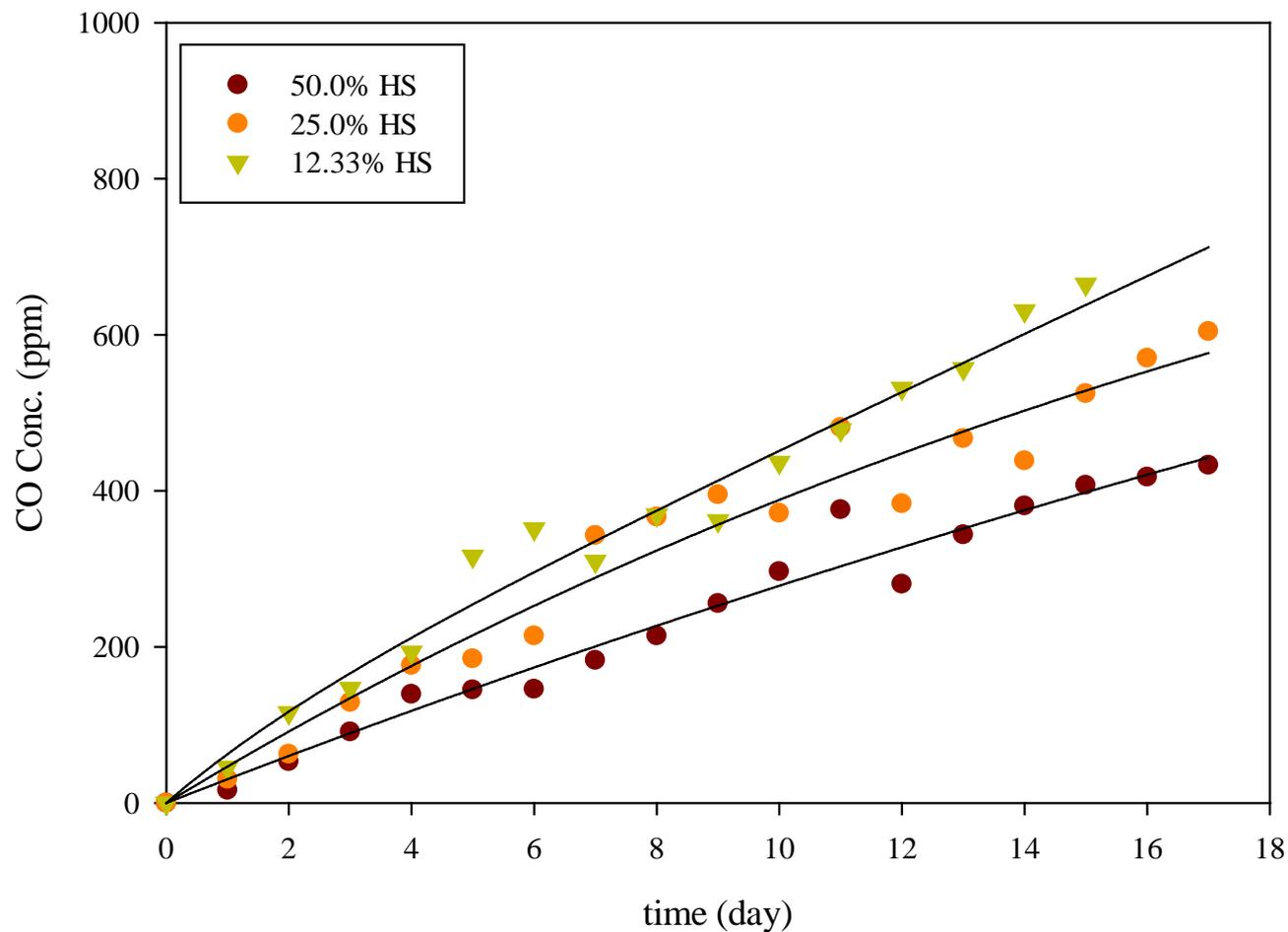
Wood type	HS %	Pellet mass
Hardwood	~ 50%	~ 18.3 kg
Softwood	~ 50%	~ 18.3 kg
Blended	~ 50%	~ 18.3 kg



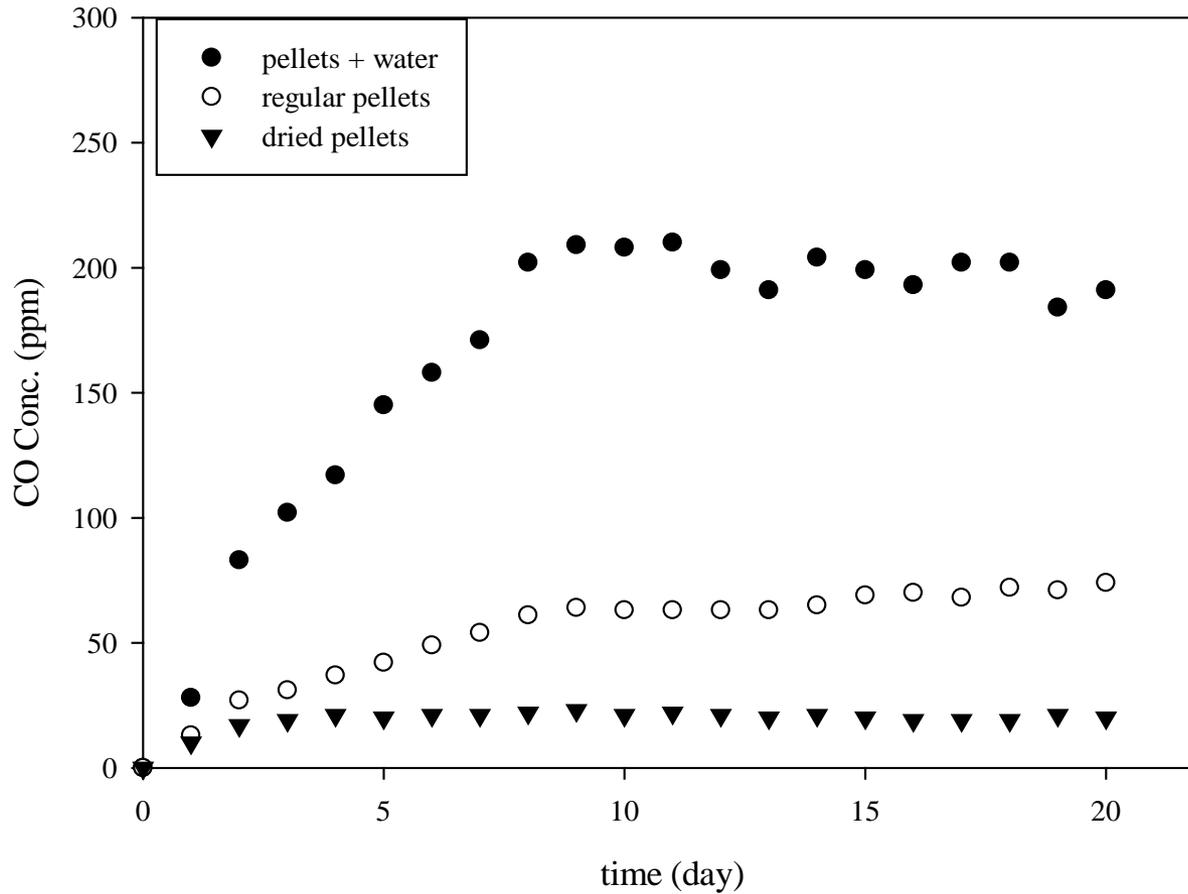
Oxygen Depletion



Volume of Head Space vs CO Off-Gassing Rate



Humidity vs CO Off-Gassing Rate



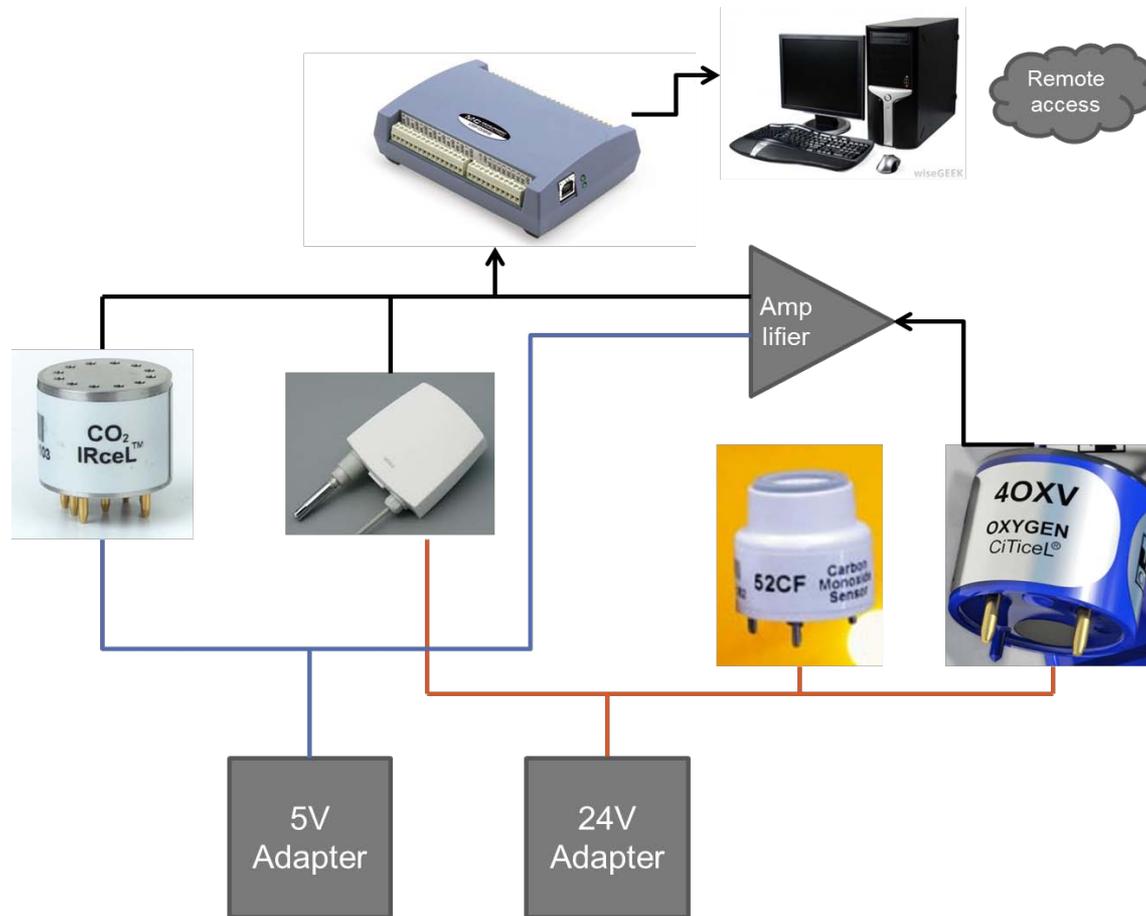
Actual Sampling Sites and Measurements

Pellet Storage in a <u>Residence</u> , Massena	CO
Saranac Lake Petrova <u>Elementary School</u> - Pellet Bin	CO
Malone <u>Middle School</u>	
Pellets Bin-Air Duct	CO location - 1, PM
Boiler Room	CO location - 3
Hallway near Storage Room	CO location - 2
Energy Cabin, Storage Bin, Clarkson Univ.	CO, O ₂ , T, RH, CO ₂
Walker Center <u>Stadium</u> , Storage Bin, Clarkson University (CU)	CO, O ₂ , T, RH, CO ₂
Wild Center, <u>Museum</u> , Tupper Lake	CO, O ₂ , T, RH, CO ₂

*SUNY-ESF CHP (Pellet Bin and Boiler Room) for CO & PM-

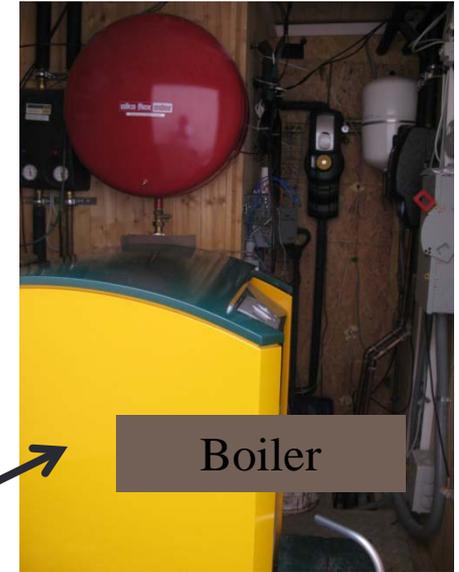
Soon!

Sensors for Monitoring



Calibration of CO sensors (0, 20, 40, 76, 200 ppm)

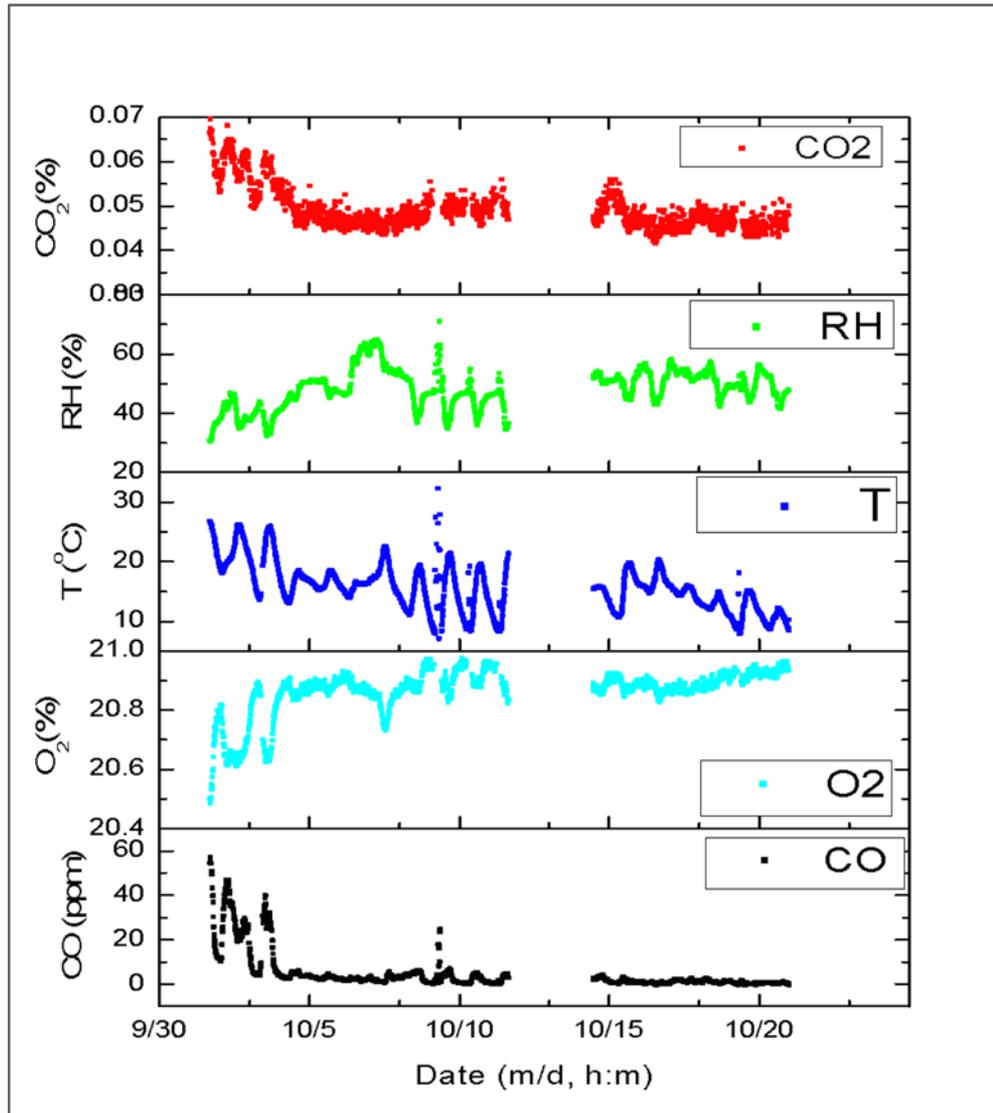
Energy Cabin Storage Bin at CU



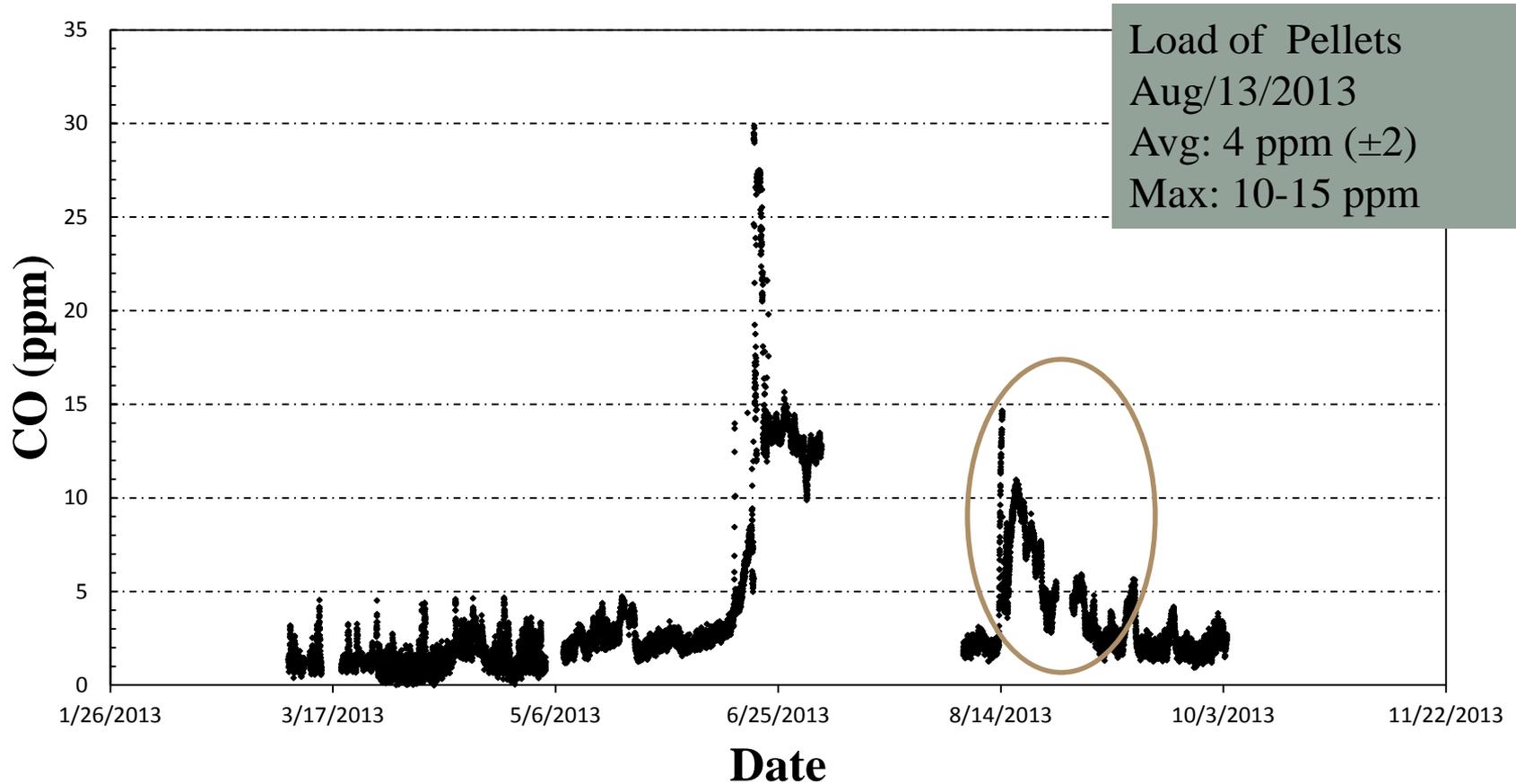
Wild Center Museum at Tupper Lake



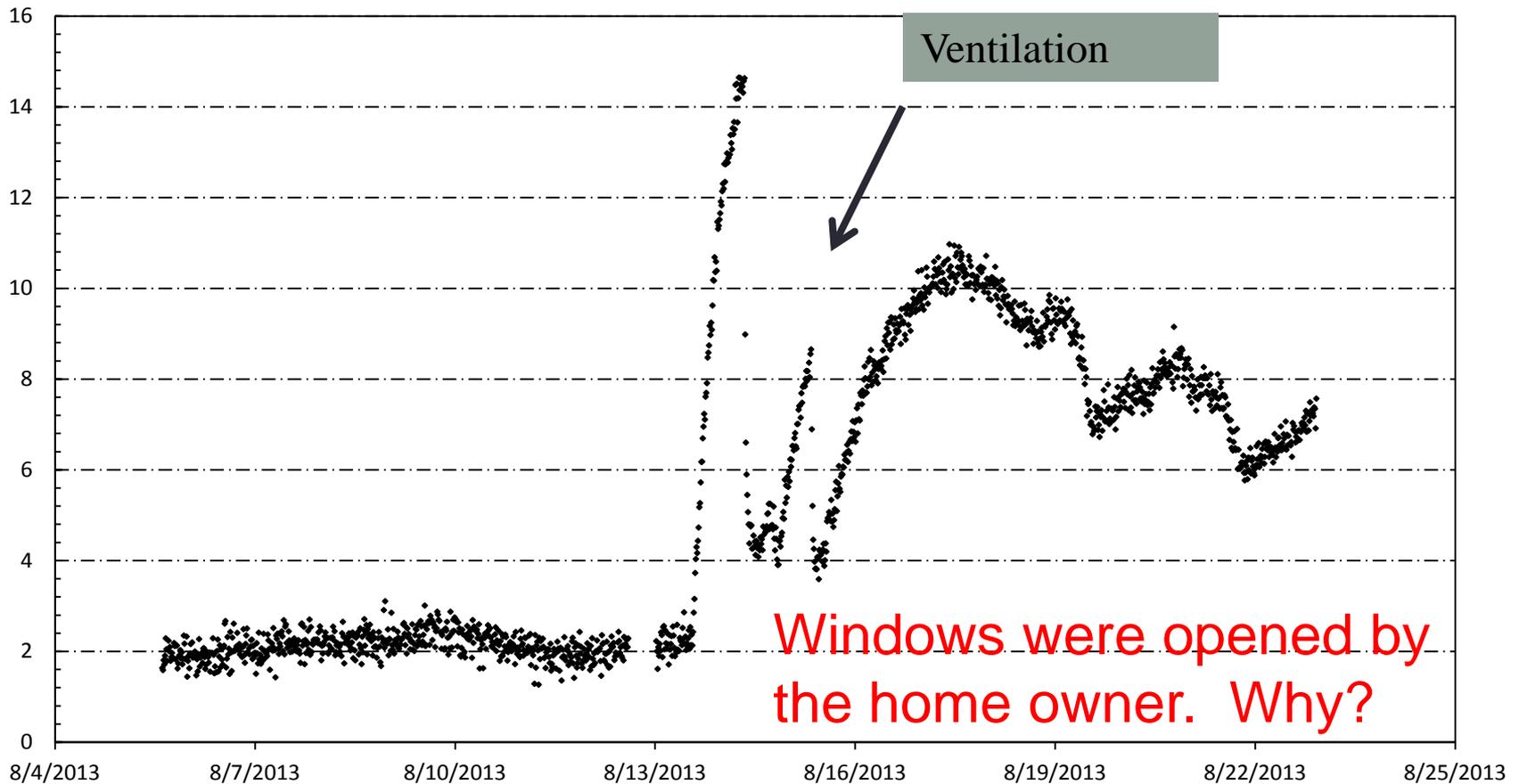
Wild Center at Tupper Lake



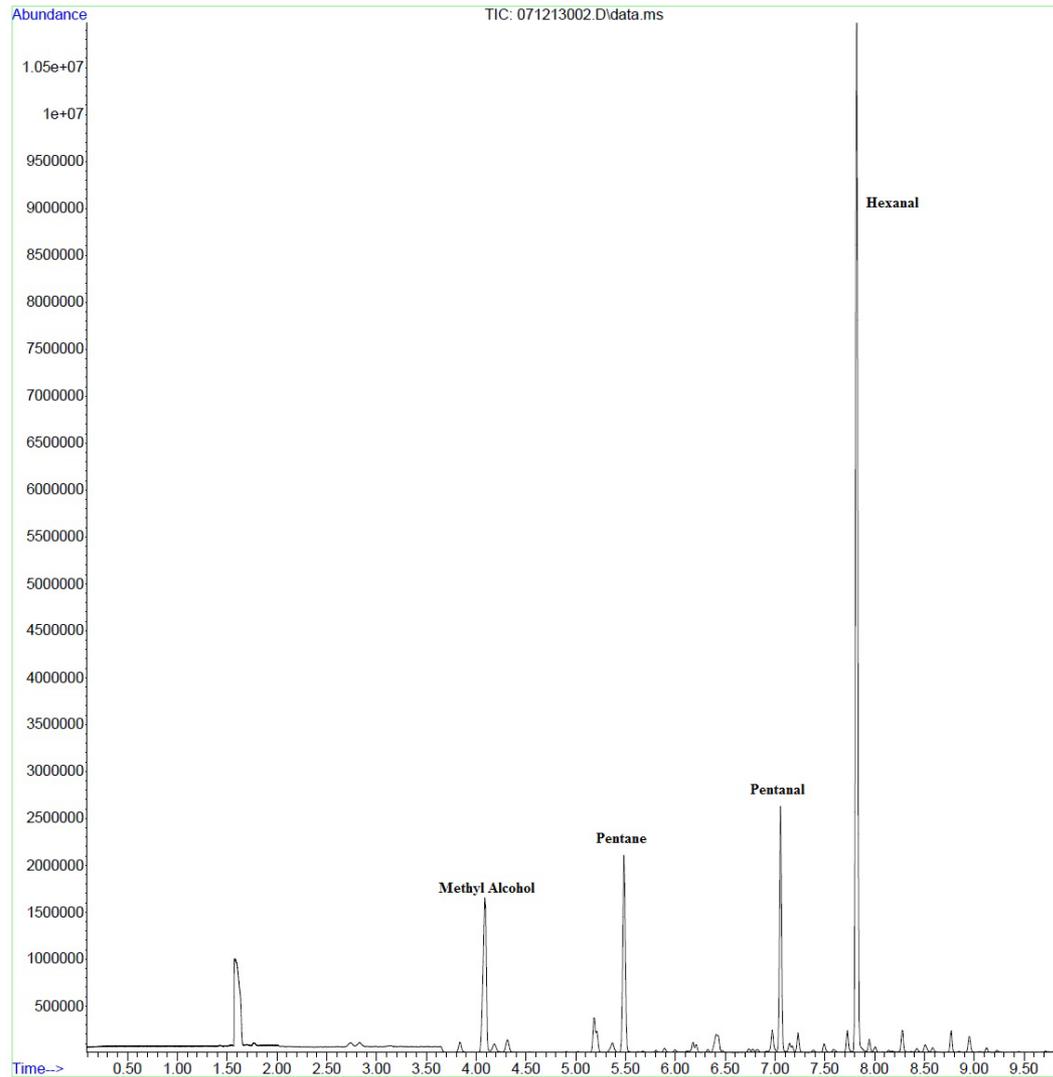
CO in Basement Residence in Massena



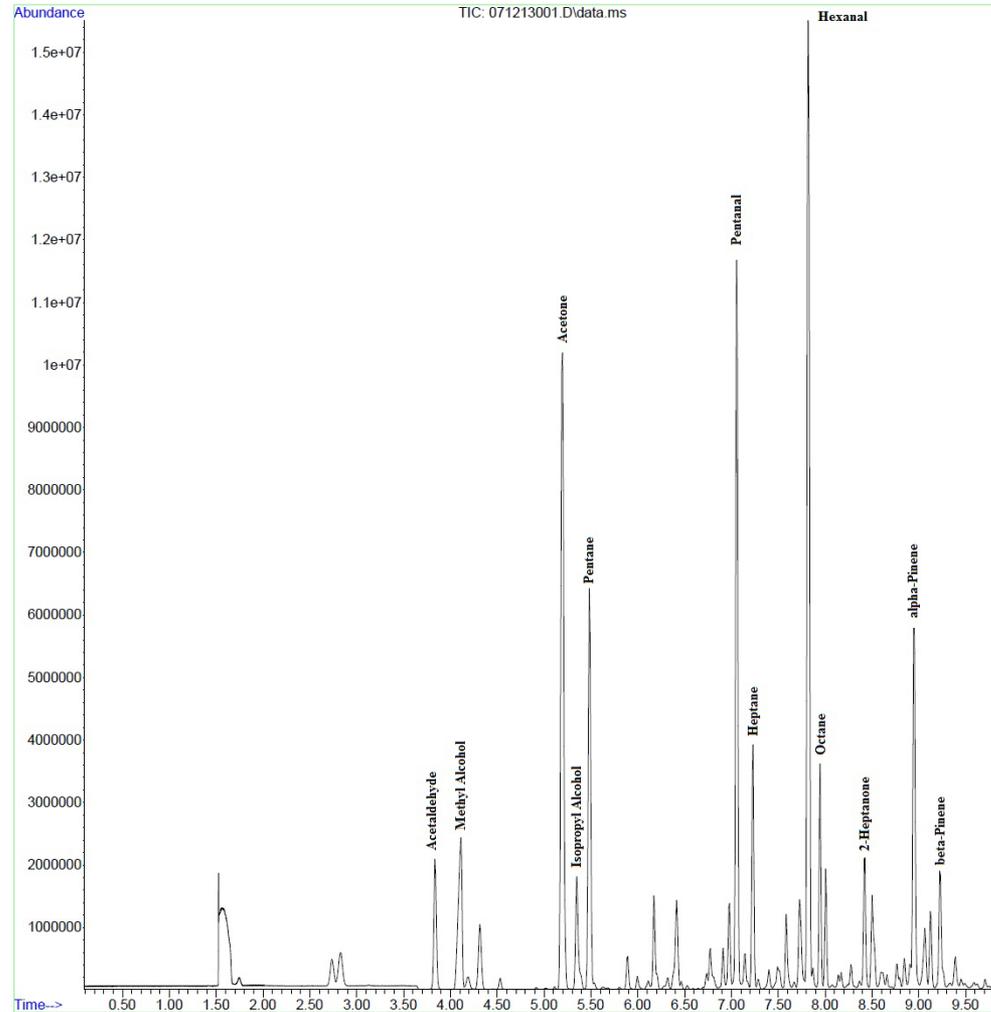
CO in Basement Residence in Massena



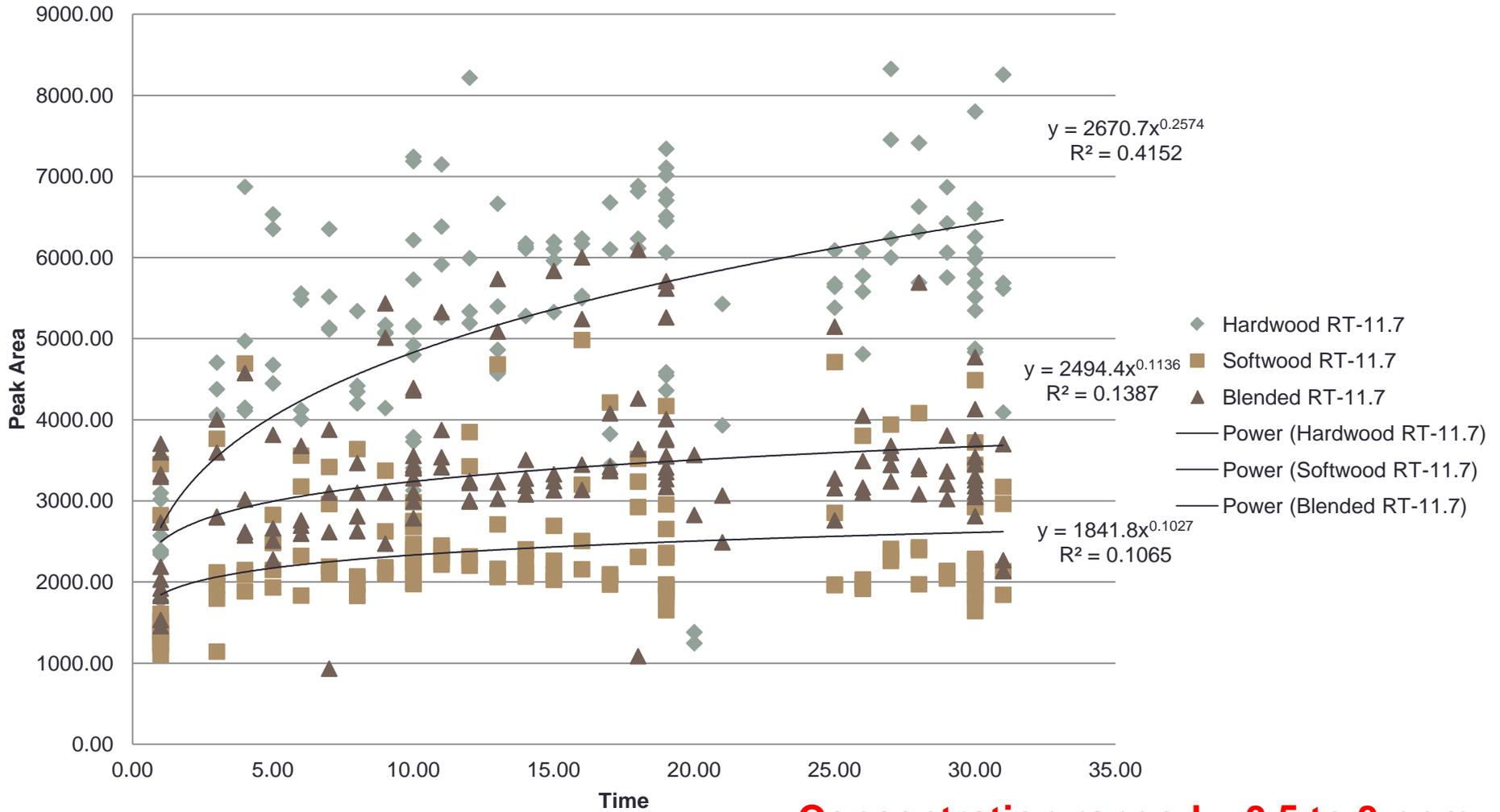
Hardwood VOC Emissions



Softwood VOC Emissions

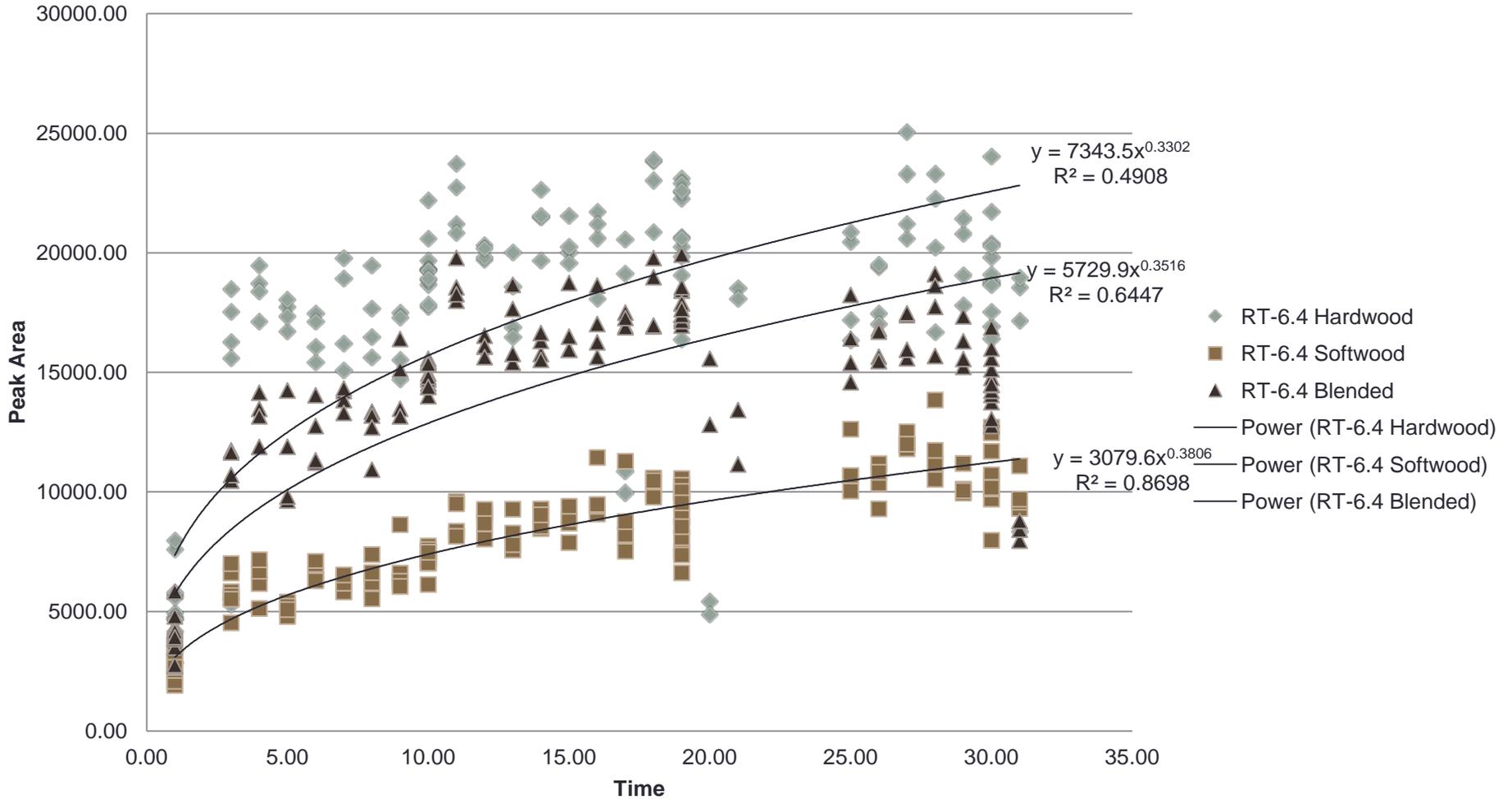


Hexanal

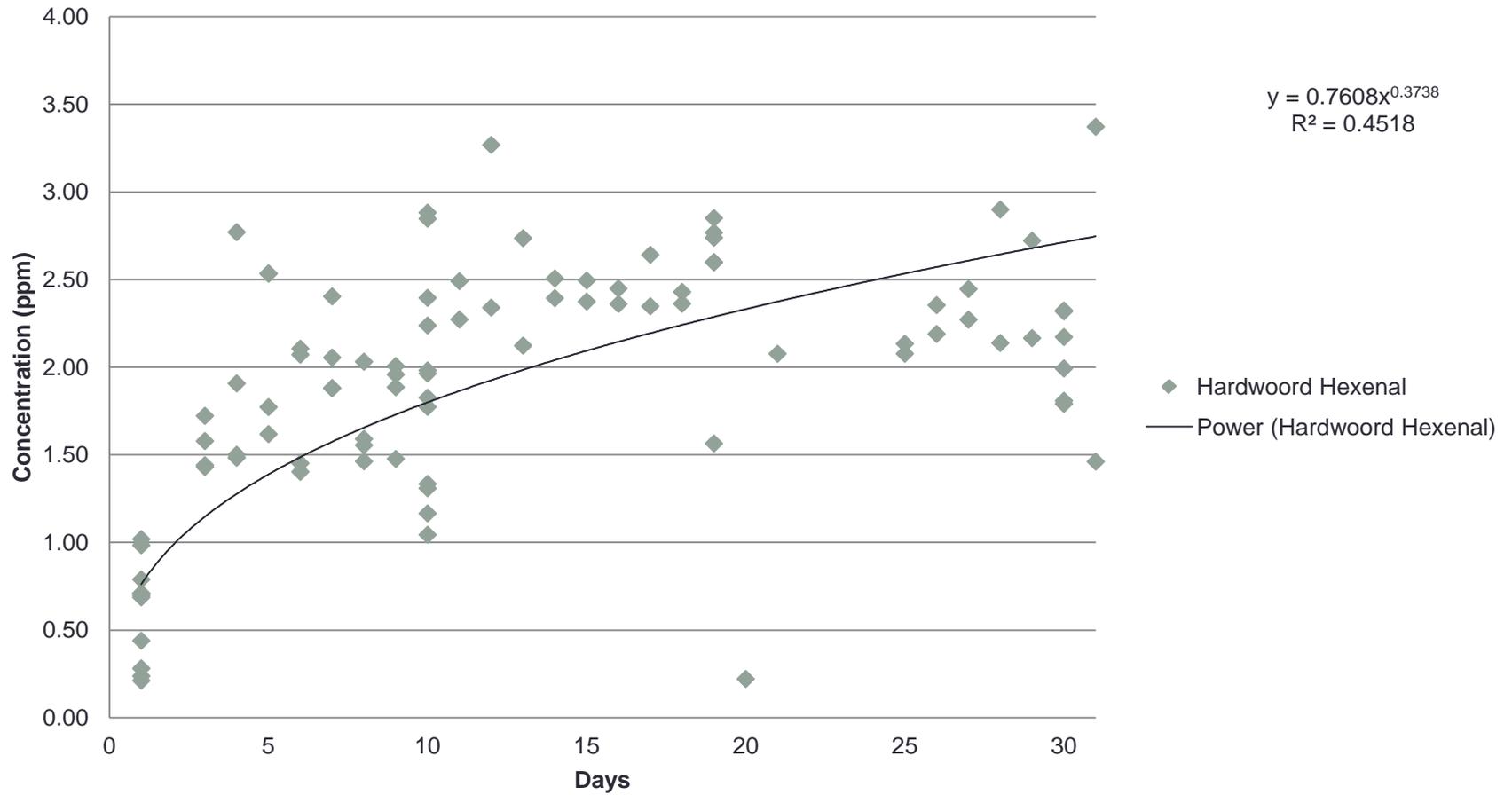


Concentration ranged – 0.5 to 3 ppm

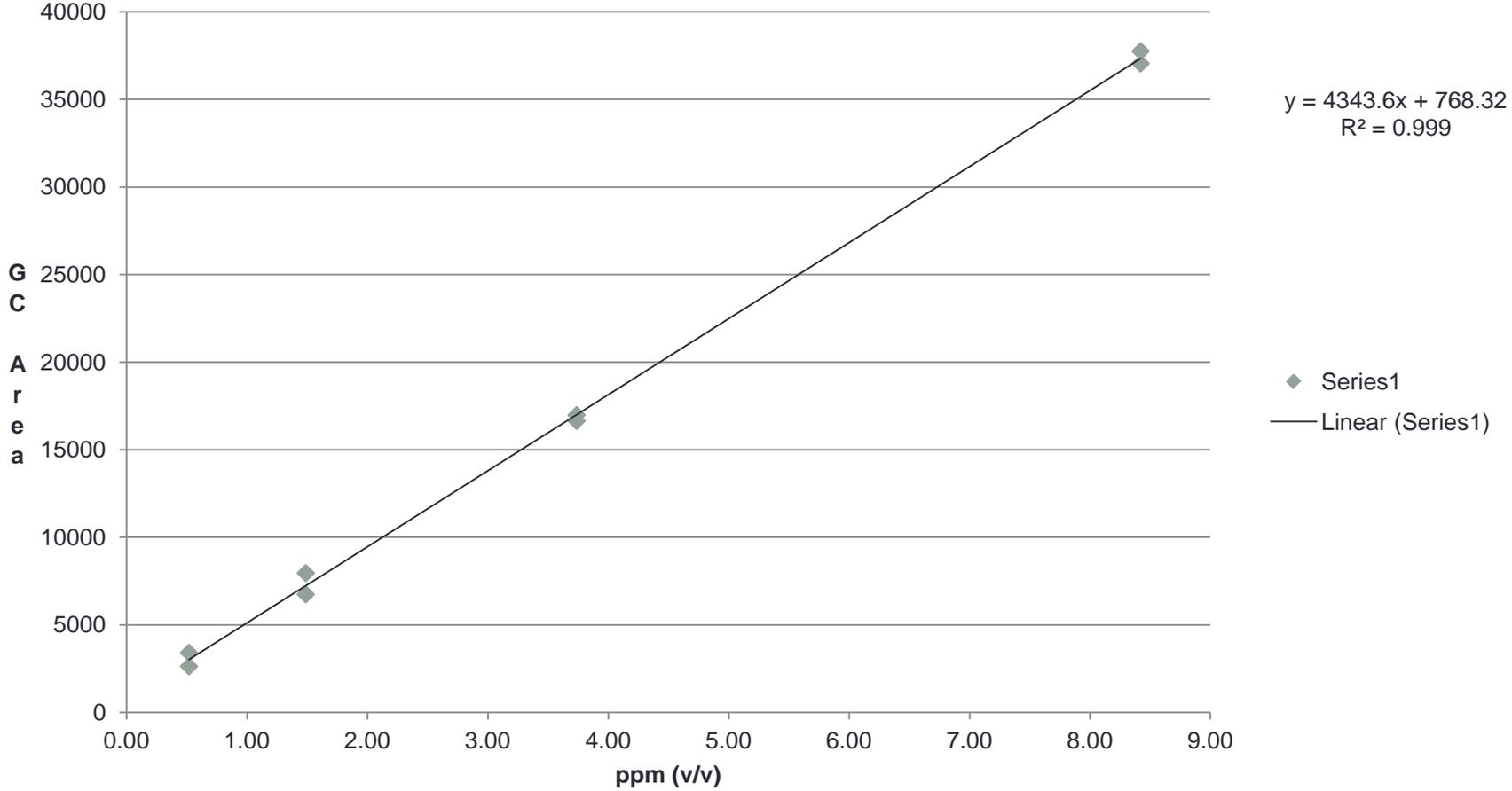
Pentenal)



Hardwood Hexenal



Calibration Hexanal



Study Results to date

- Softwood pellets were found to emit more CO and VOCs than hardwood pellets and typically in higher concentrations.
- A variety of compounds collected in the air samples were successfully identified with a gas chromatograph/mass spectrometer and quantified.
- From the calculated concentrations the emission rates of the CO and VOC's in the headspace were calculated and will be used to estimate concentrations in buildings.
- Understanding the rates of contaminant off-gassing will lead to better ventilation designs for stored wood pellets in homes, schools, and businesses.

Confined Space Entry

- Two Dead, Five Injured in Confined Space Incident in Oregon
- Worker Dies While Cleaning Freon 113 Degreasing Tank in Virginia
- Carbon Monoxide Kills Three Volunteer Firefighters Inside Well in Pennsylvania
- Waste-Water Treatment Plant Operator Drowns in Recirculation Pit in Iowa
- Two Railroad Repair Workers Asphyxiated in Damaged Tank Car



Carbon Monoxide Hazard!

Contact Env. Health & Safety (x6640) for a confined space entry permit before entering.

DANGER Recognition



CONFINED SPACE
AUTHORIZED
PERSONNEL ONLY



Evaluation



Control





OHSA Compliant Confined Space Training

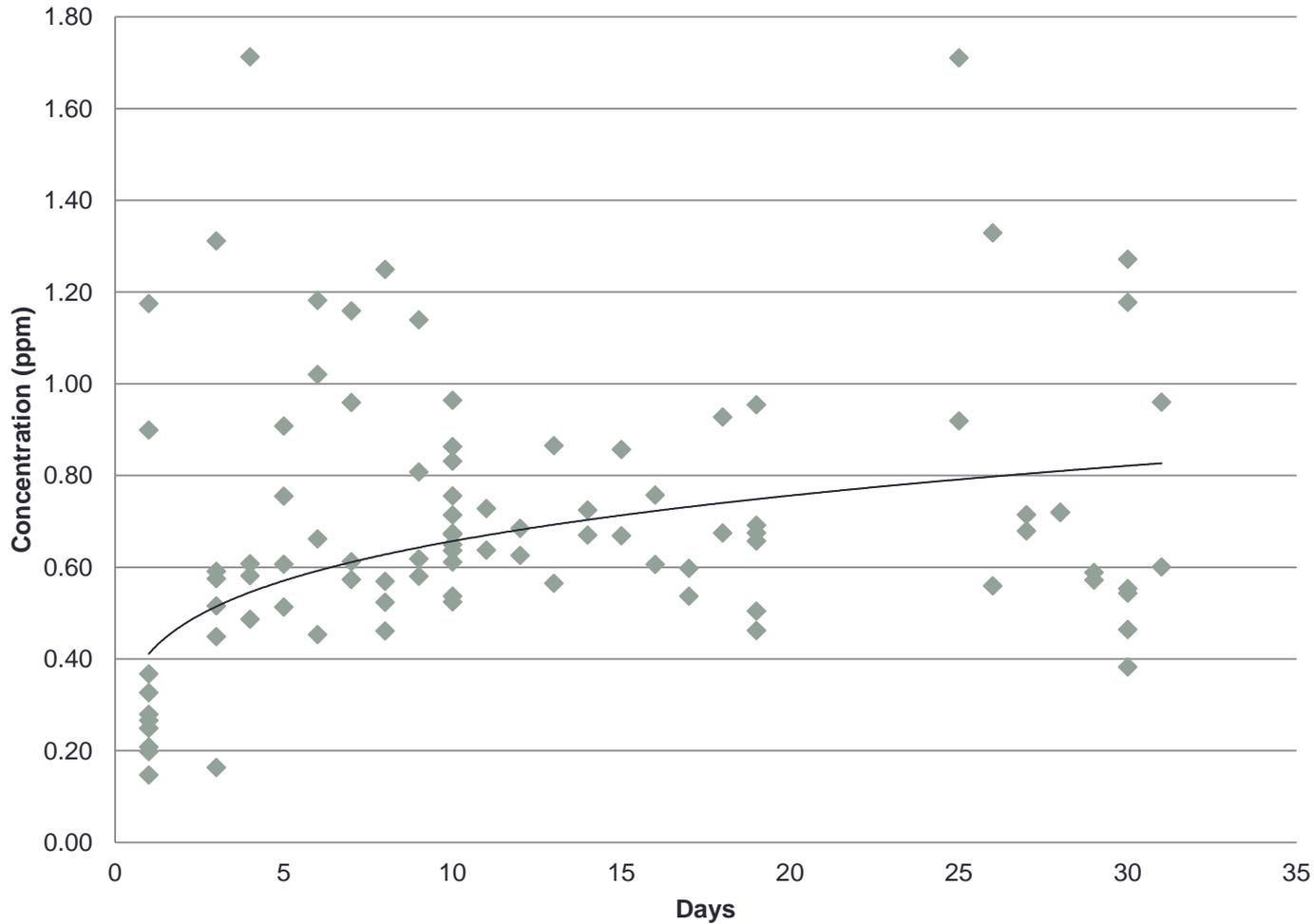
- 1910.146
Permit Required
Confined Space
- NY state
standard
applies for
Public sector
workers.
- No standard for
residence.

Step #	Process	Complete
1.	Isolate the Space from all hazards	
	a. Remove unauthorized personnel form the site of entry	
	b. LOTO	
	c. Blocking inlets, etc.	
2.	Ventilate the space (if required)	
4.	Fill out the Entry Permit	
5.	Evaluate the space	
6.	Test the atmosphere	
	a. Enter atmosphere readings on the permit	
	b. Place the completed permit on or near the PRCS	
7.	Enter the space and proceed with work	
	a. Is Supervisor available?	
	b. Attendant at the entry site	
	c. Harness	
	d. Required PPE	
	e. Retest atmospere as needed / required	
8.	When the job is done:	
	a. Remove all personnel, tools and debris from the space.	
	b. Close the space	
	c. Cancel the permit	
	d. Review the job with the employer (hazards, problems, etc.)	

Questions?



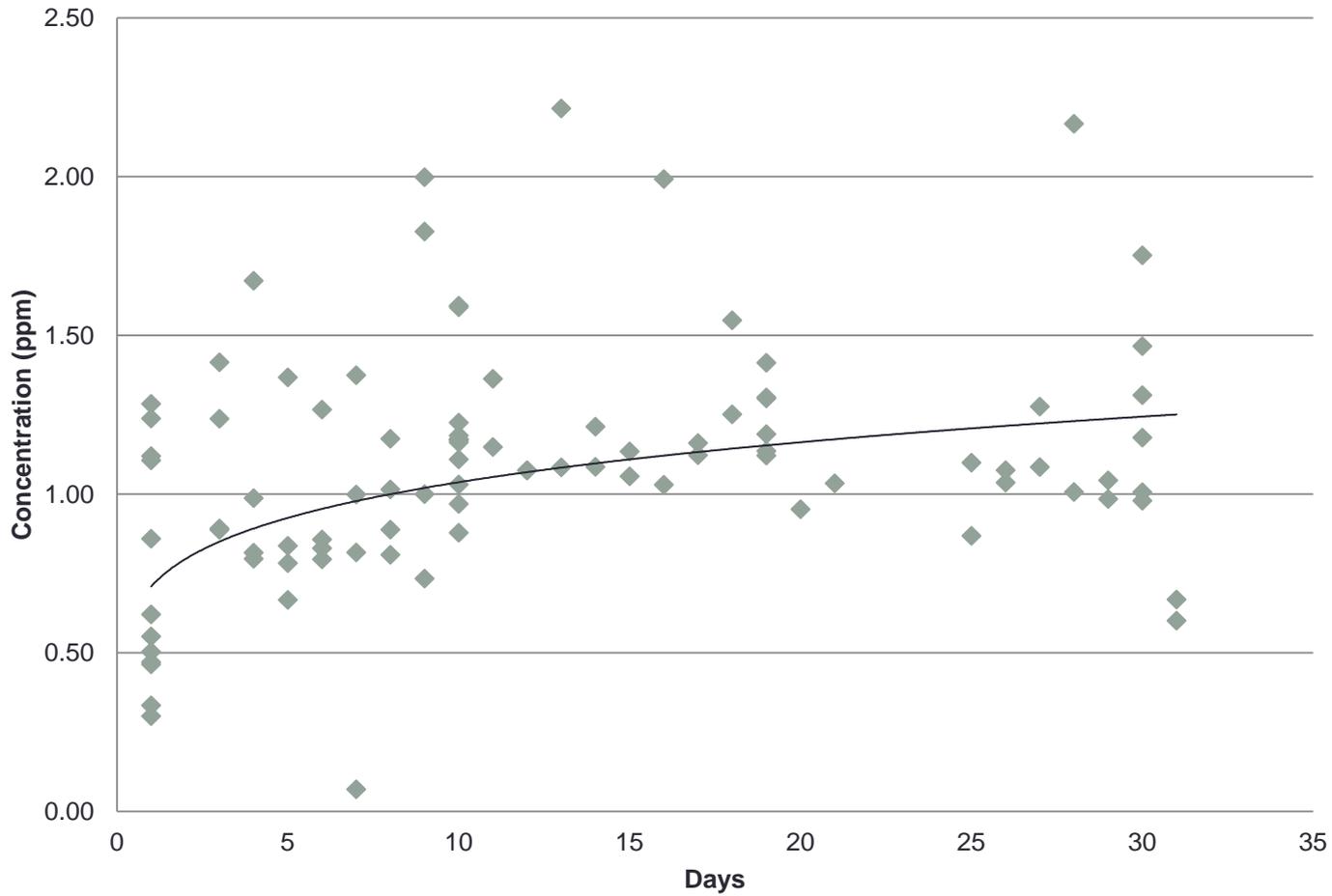
Softwood Hexenal



$y = 0.4115x^{0.2032}$
 $R^2 = 0.2009$

- ◆ Softwood Hexenal
- Power (Softwood Hexenal)

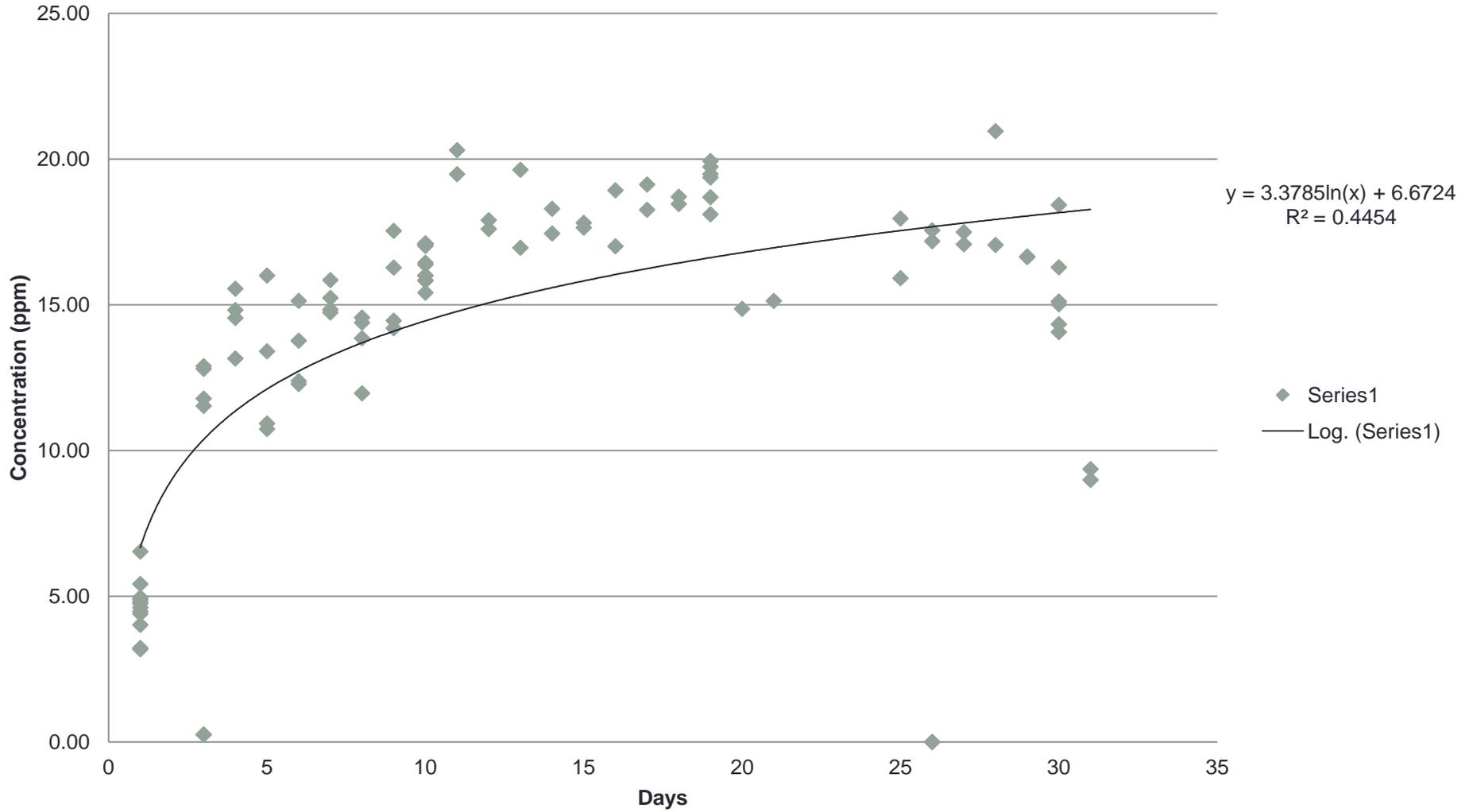
Blend Hexenal



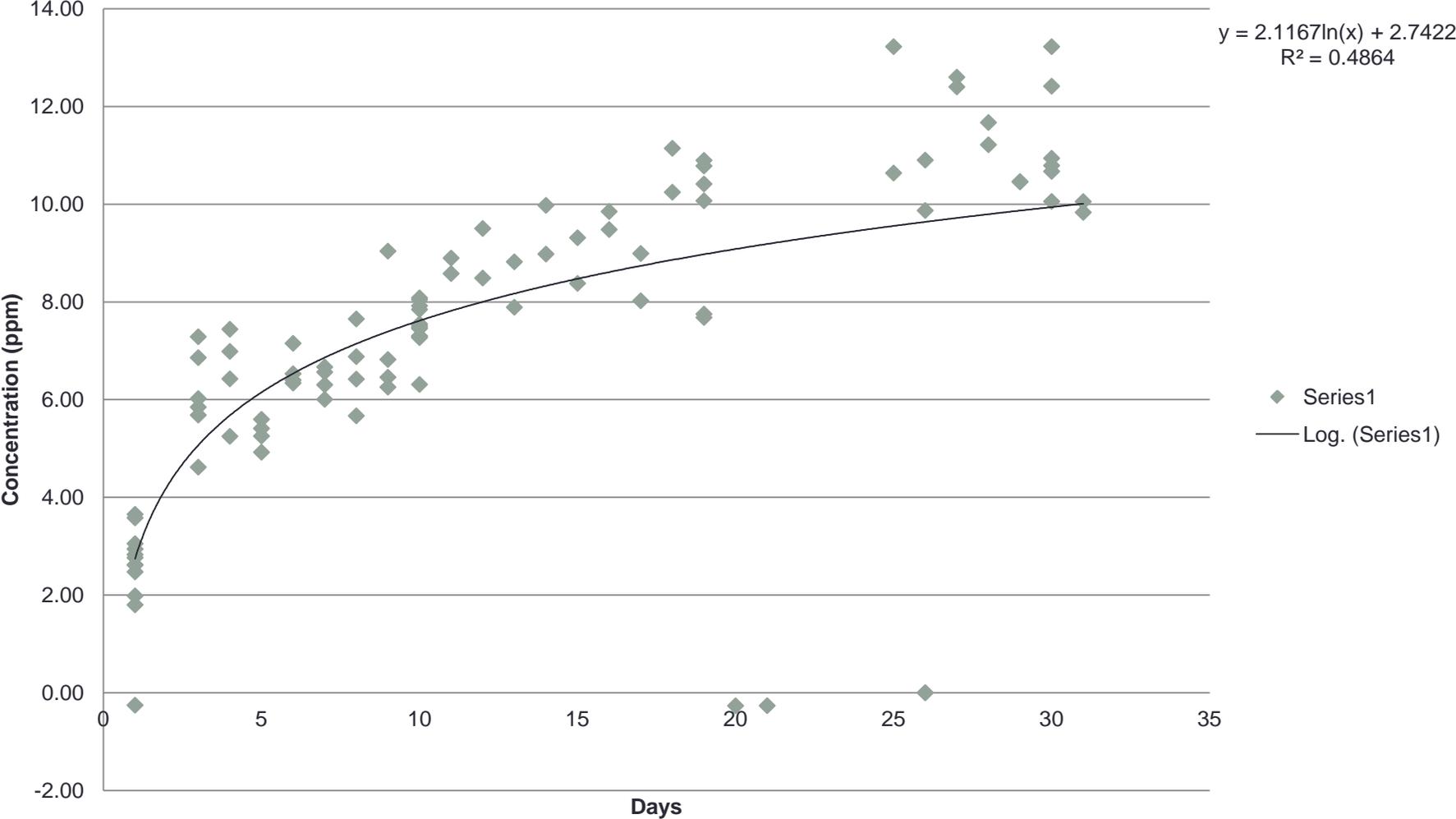
$y = 0.7088x^{0.1654}$
 $R^2 = 0.1476$

- ◆ Blend Hexenal
- Power (Blend Hexenal)

Pentanal Blend



Softwood Pentanal



Hardwood Pentanal

