Yeast Flatulence or Eructation (CO_2):

What are the effects and how to control It

Dave Huizen, CIH

Professor of Occupational Safety and Health

Grand Valley State University

301 Fulton St W

Grand Rapids MI 49504

huizend@gvsu.edu

Yeast Flatulence or Eructation (CO_2):

Why this study?

- Tremendous growth in small brewing operations
- Safety and Health – An after thought?
- Little or no data on CO_2 exposures in breweries
- Little data on effects of CO_2 at levels < 10,000 PPM
- Curious on the impact of combined risk on health

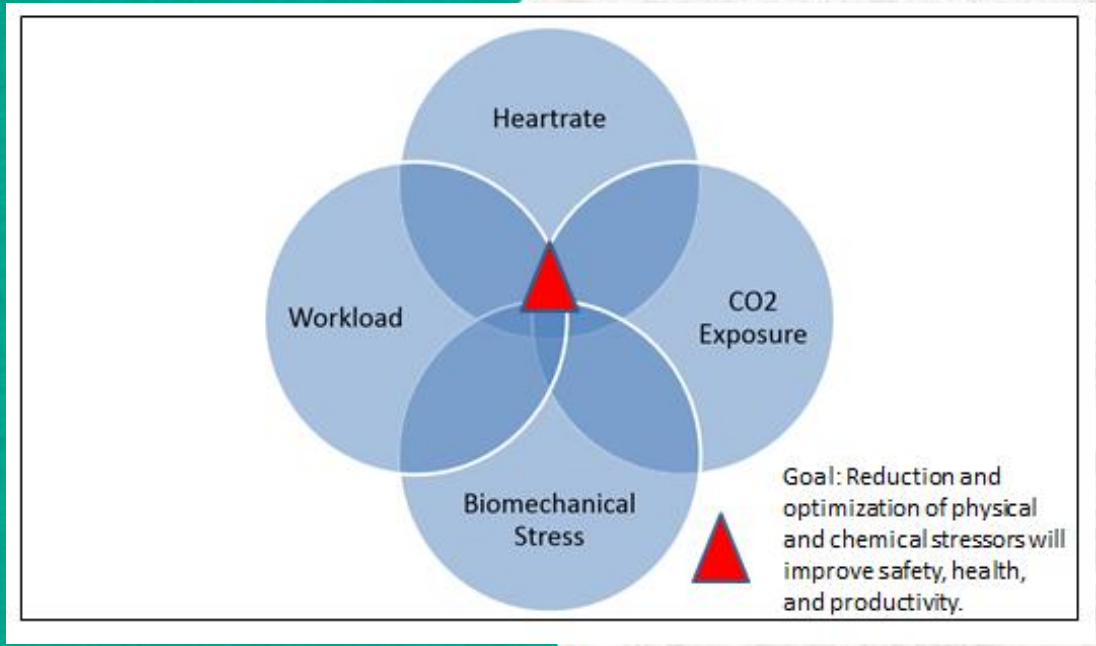
Yeast Flatulence or Eructation (CO_2):

What are the takeaways of this presentation

- What is Combined Risk
- What CO_2 levels are found in different sized breweries
- What variables can impact those CO_2 levels
- What effect do lower CO_2 levels have on heart rate
- What are effective control measures to reduce combined exposure

Combined Risk Exposure

Yeast Flatulence or Eructation (CO_2):

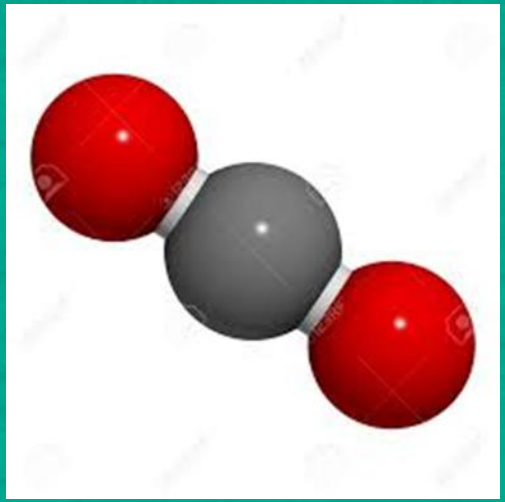


What is Combined Exposure Risk?

- Multiple exposures causing the same health effect
- The increase in combined risk is greater than one exposure at a time
- Could be additive, multiplicative, or synergistic
- Could be occupational, environmental, or community exposures.

Risk #1

Carbon Dioxide



What do we know about CO_2

- Odorless – acidic smell at high concentrations (carbonic acid formation)
- Colorless
- Slightly pungent acid taste
- Non-flammable
- Density – 1.98 kgs/m^3 -1.67X greater than air
- Concentration in ambient air ~400 PPM
- Produced by biological methods or combustion
- Variety of uses – photosynthesis to refrigeration

Risk #1

Carbon Dioxide

Current Exposure levels to CO_2

- OSHA / ACGIH 8 hour – 5000 PPM
- ACGIH TLV STEL* – 30,000 PPM
- NIOSH IDLH – 40,000 PPM

* 15 minute exposure limit

Known Health Effects of CO_2

Concentration of CO_2 (PPM)	Health Effect
3,000 to 5,000 PPM	Slight Increase in Respiration
5,000 PPM	5% Increase in Respiration
10,000 PPM	Fatigue, Anxiety, Loss of Energy
20,000 PPM	50% Increase in Respiration, Severe Headache
50,000 PPM	Violent panting and fatigue to the point of exhaustion merely from respiration & severe headache. Prolonged exposure at this level could result in irreversible health effects
90,000 PPM	Death in 5 Minutes

Risk #1

Carbon Dioxide

Low level CO2 Effects from Literature

- Increased respiration rate
- Increased heart rate
- Headache
- Cognitive impairment
- Increased fatigue

Risk #2

Biomechanical Stress

Health effects of Ergonomic Stressors

- Overexertion injuries
- Musculoskeletal disorders
- Increased physical exertion
- Increased heart rate
- Increased fatigue

Risk #3

Workload

Health Effects of Workload

- Increased stress
- Headaches
- Increased heart rate
- Increased fatigue

Methodology

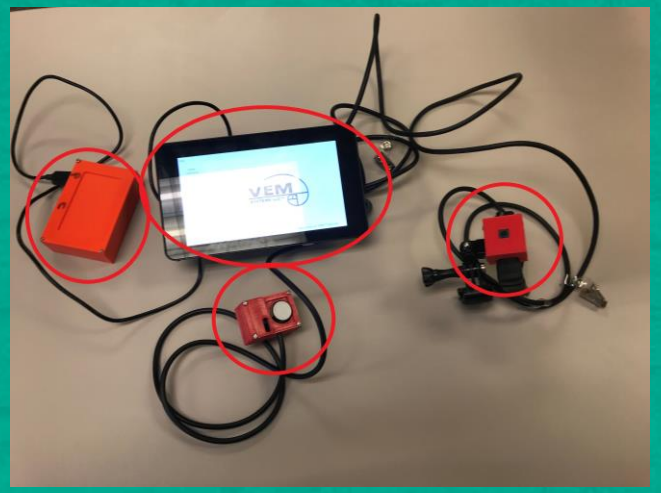
Methodology: General

Data Gathering: Who and Where

- Small, Medium, and Large “Craft” Breweries
  - Walk around at different days and times
- Three jobs tasks evaluated
  - Cellar
  - Canning/Packaging
  - Barrel Filling

Methodology:

CO2 and Heart Rate Data Collection

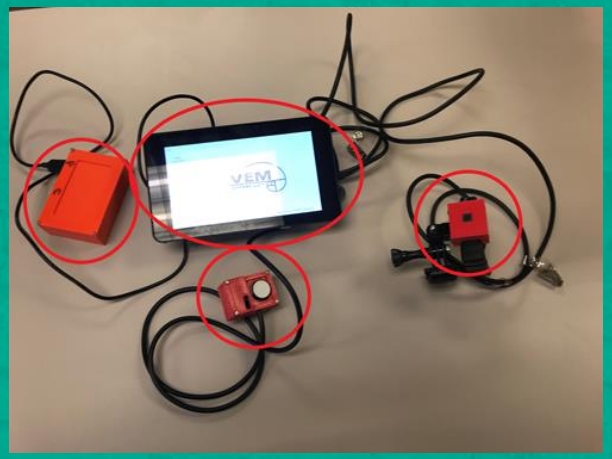


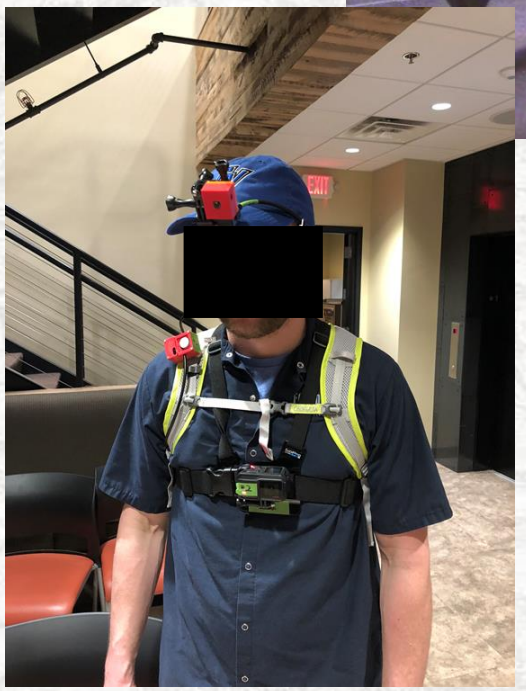
Video Exposure Monitoring (VEM™)

- Video Feed
  - VEM system wired camera
  - Garman VIRB
- CO_2 Sensor
  - CO2 Meter - MinIR 5% CO2 Smart LED Sensor (NDIR)
- Heartrate Sensor
  - Garmin wrist fitness tracker
- Raspberry PI computer
- Proprietary software

Methodology:

CO2 and Heart Rate Data Collection



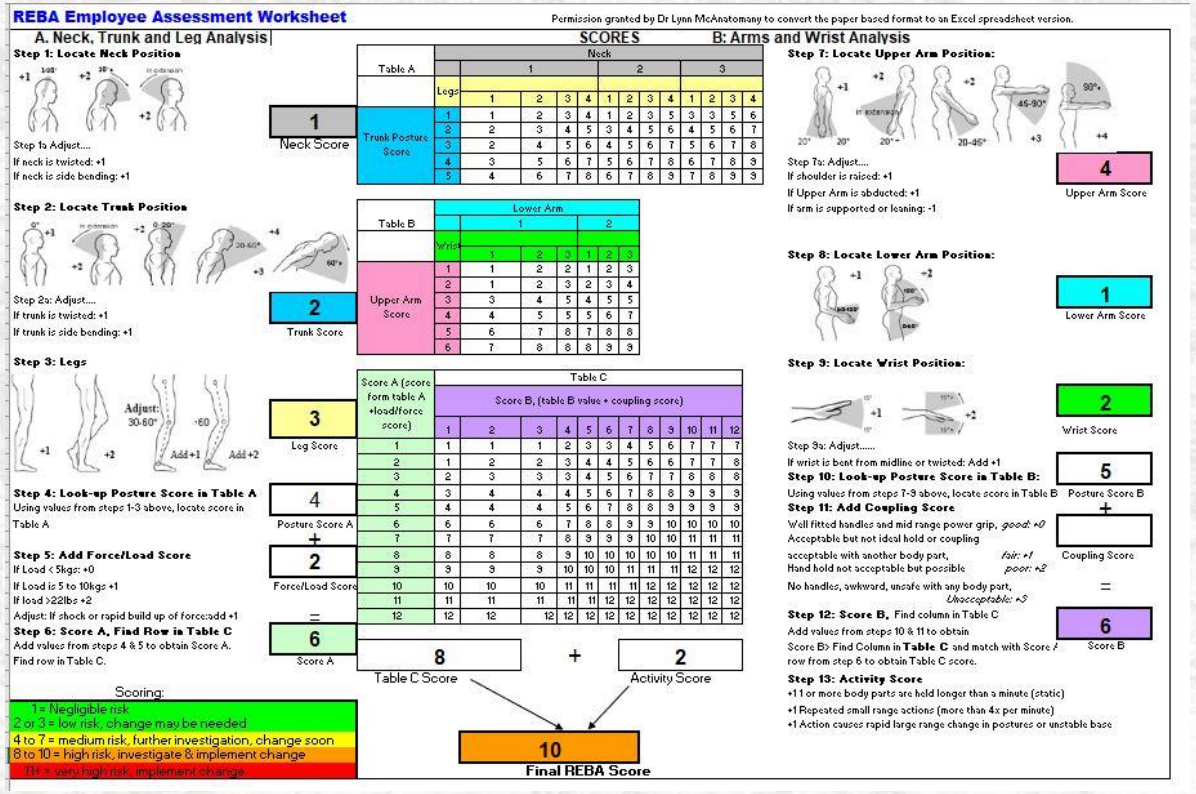


Methodology:

Biomechanical Stress

Biomechanical Risk Factor

- Rapid Entire Body Assessment - REBA

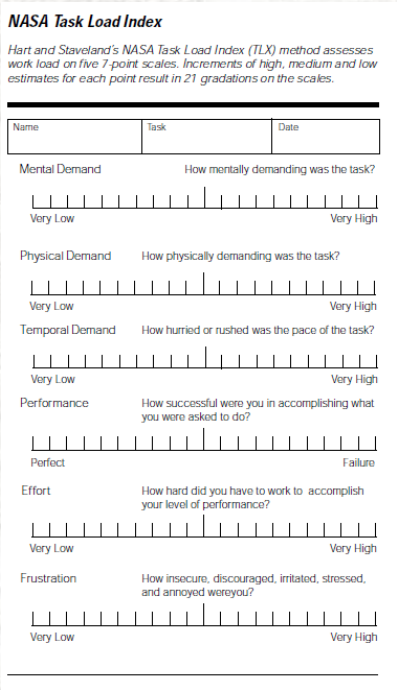


NASA – Task Load Index (TLX)

Methodology: Workload

Mental demand	How much mental activity was required? Was the task easy or demanding, simple or complex?
Physical Demand	How much physical activity was required? Was the task easy or demanding?
Temporal Demand	How much time pressure did you feel due to the pace of the task? Was the pace slow or rapid?
Overall Performance	How successful were you in performaing the task and how satisfied were you with your performance?
Frustration Level	How irritated, stressed, or annoyed were you versus relaxed, content or complacent during this task?
Effort	How hard did you have to work (mentally and physically) t oaccomplish your level of performance?

- Six Subscales
- Collected via I-Pad



NASA Task Load Index

Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales.

Name	Task	Date

Mental Demand — How mentally demanding was the task?

Very Low — Very High

Physical Demand — How physically demanding was the task?

Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?

Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?

Perfect — Failure

Effort — How hard did you have to work to accomplish your level of performance?

Very Low — Very High

Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou?

Very Low — Very High

Results

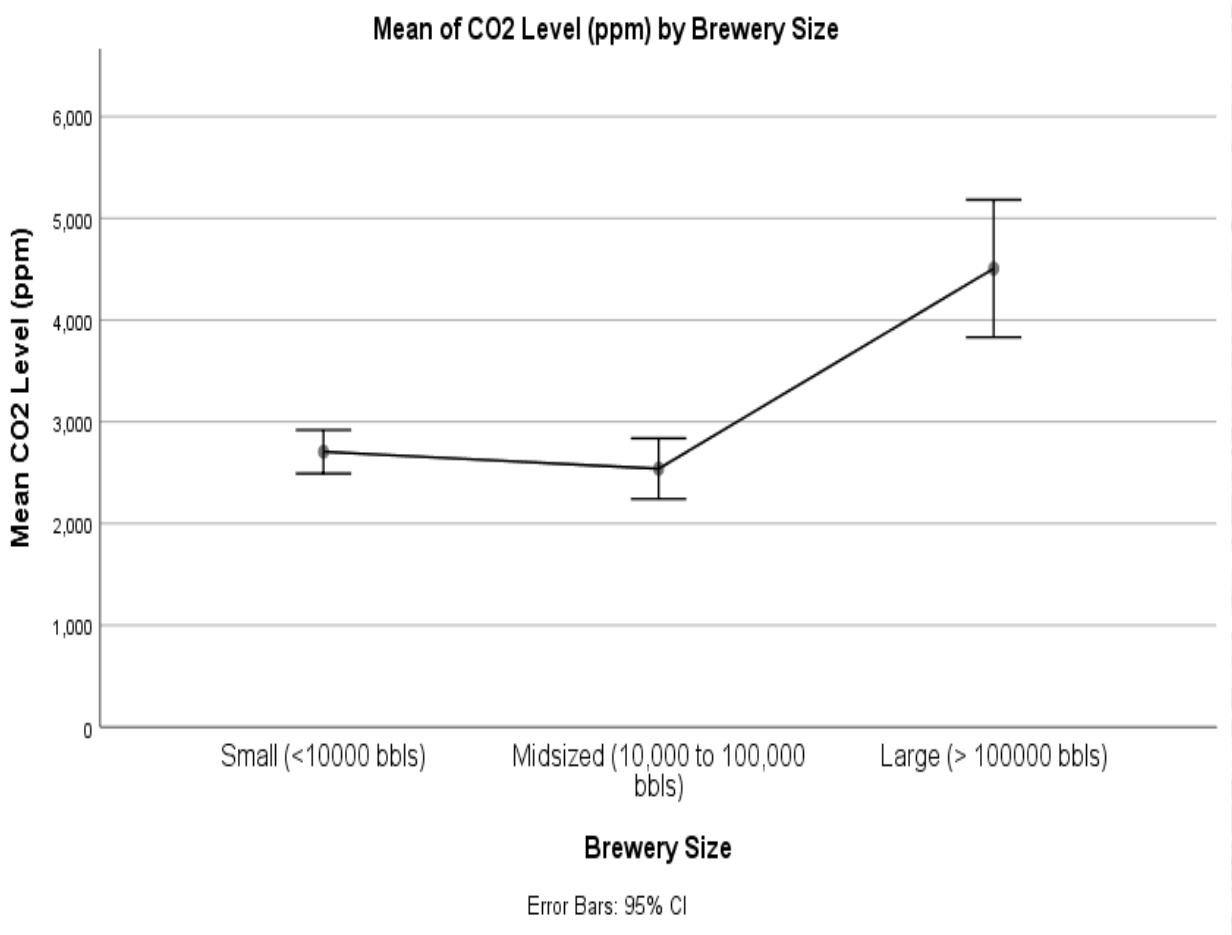
Phase 1 – What Are the CO_2 Levels Found in Different Sized Breweries

Brewery Demographics

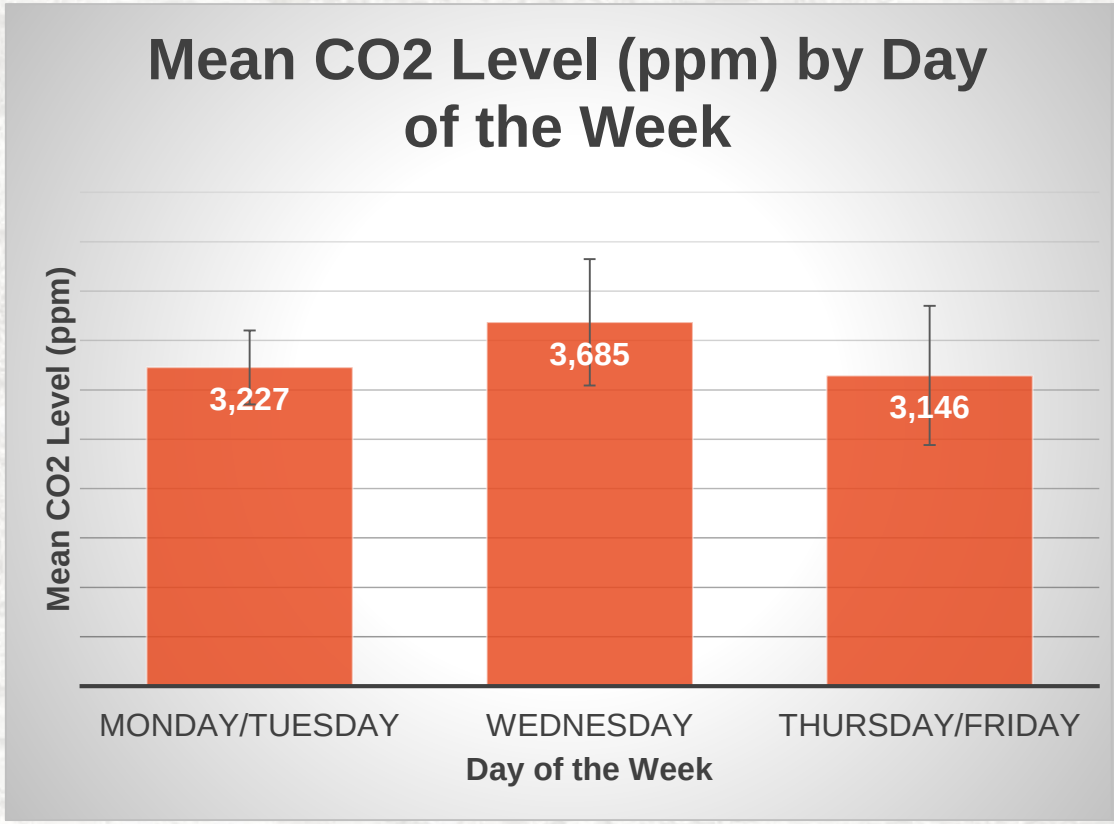
Brewery	A (Small)	B (Medium)	C (Large)
Annual Production Volume	5000 Barrels (bbls)	13,000 bbls	680,000 bbls
Brewery Physical Size	5200 ft^2	11,000 ft^2	133,500 ft^2
Amount Active Fermentation during sampling periods	180-250 bbls	600 – 660 bbls	600 – 2800 bbls*
Speed of Packaging Lines	32 cans/minute	50 bottles per minute 40 cans per minute	120-750 can/minute 450 bottles/minute

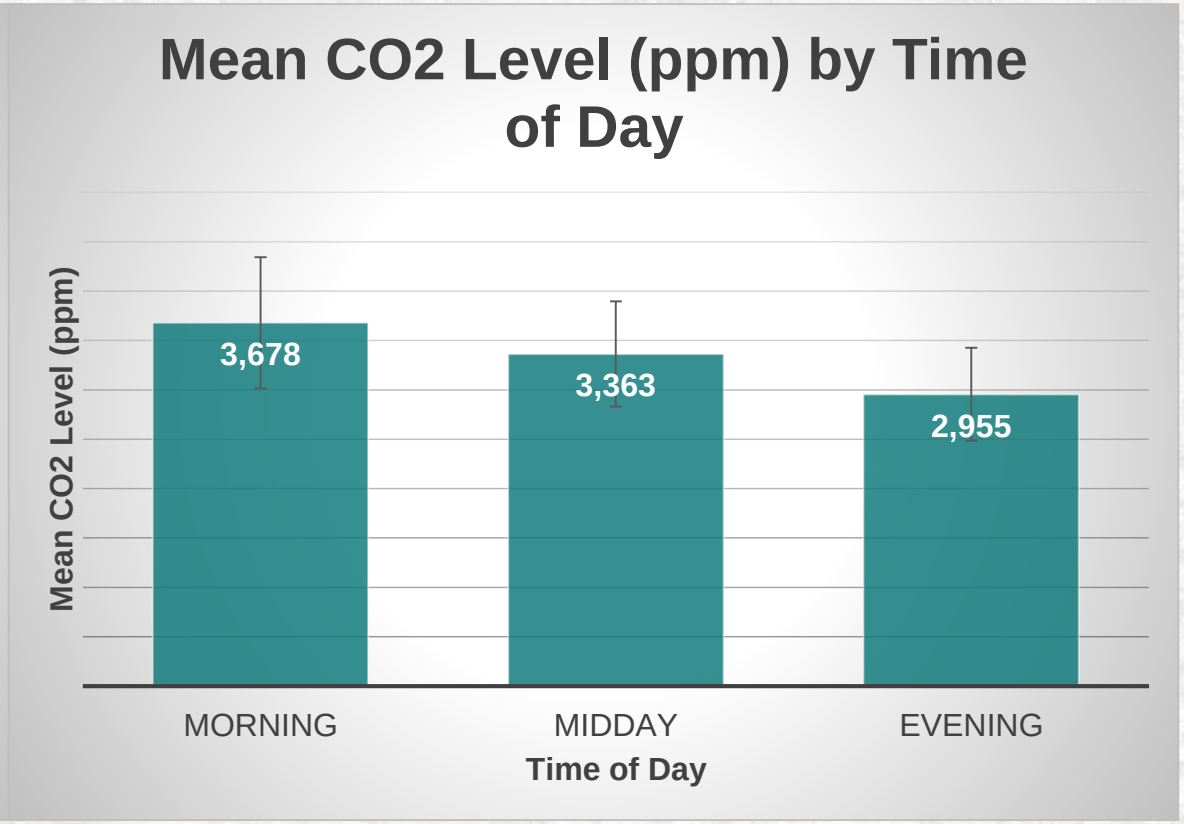
Overall CO_2 Level In Craft Breweries by Size

Brewery Size	Arithmetic Mean (ppm)	Standard Deviation (ppm)	95th Percentile Point Estimate (ppm)	$UTL_{95\%,95\%}$ (ppm)
Small	2710	652	3952	4470
Medium	2540	880	4509	5510
Large	4510	2250	8756	10800

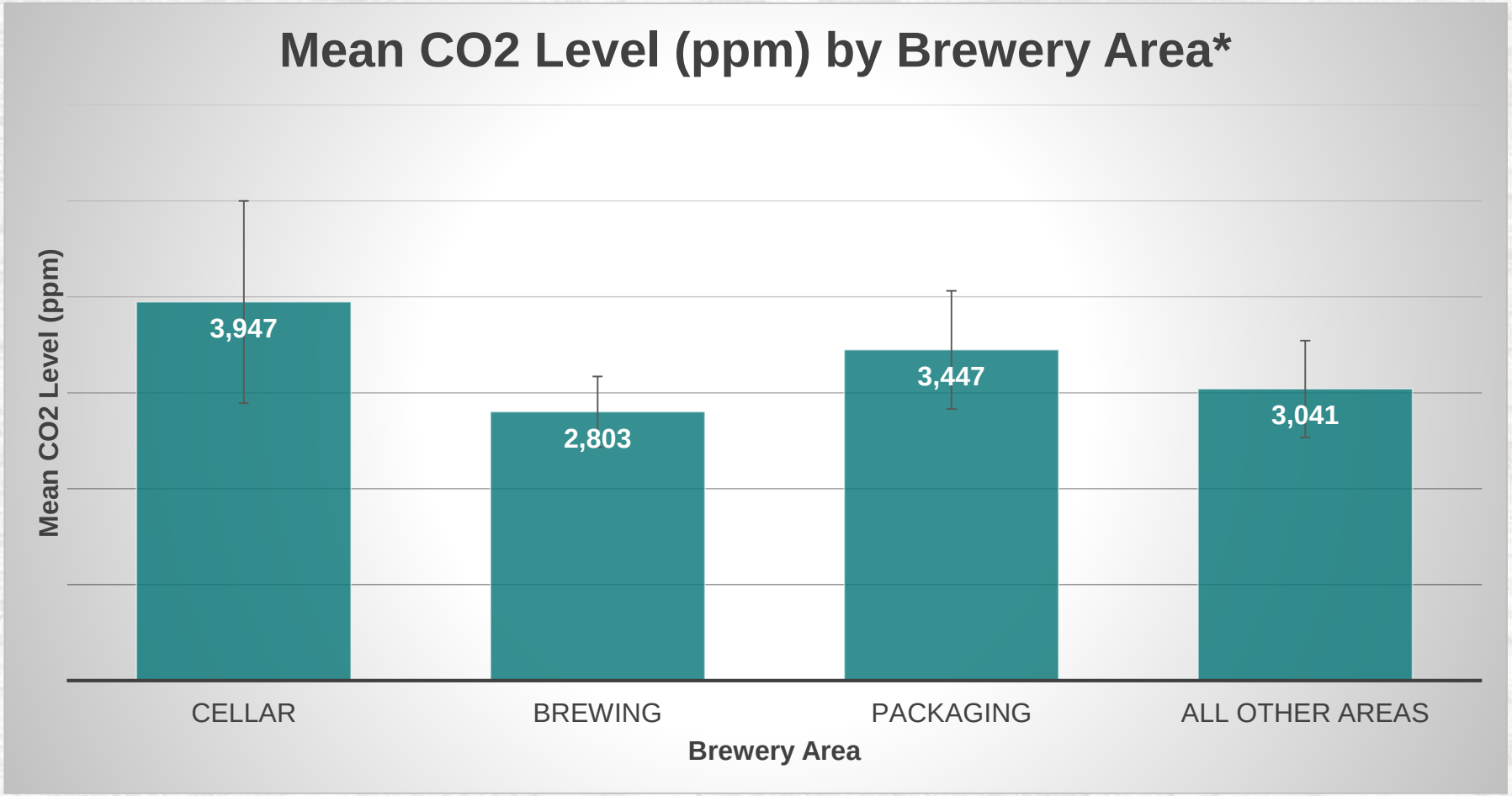


Overall CO_2 Levels by Day and Time

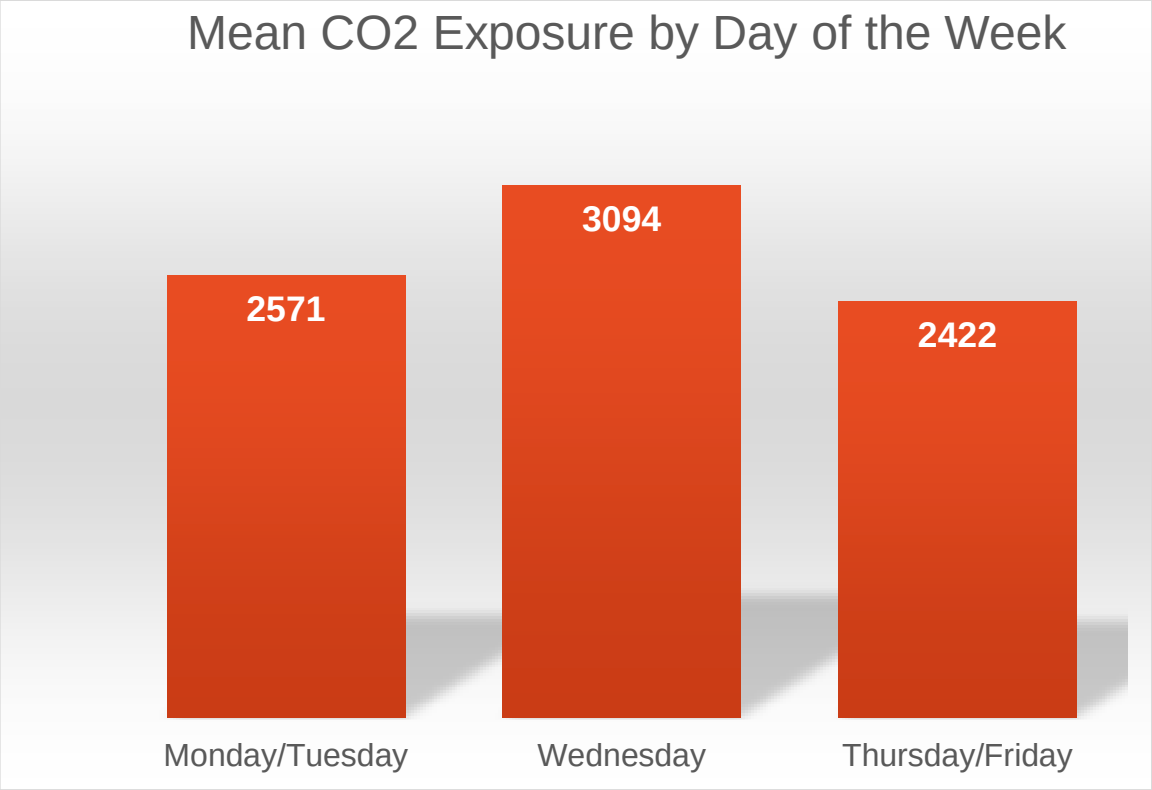


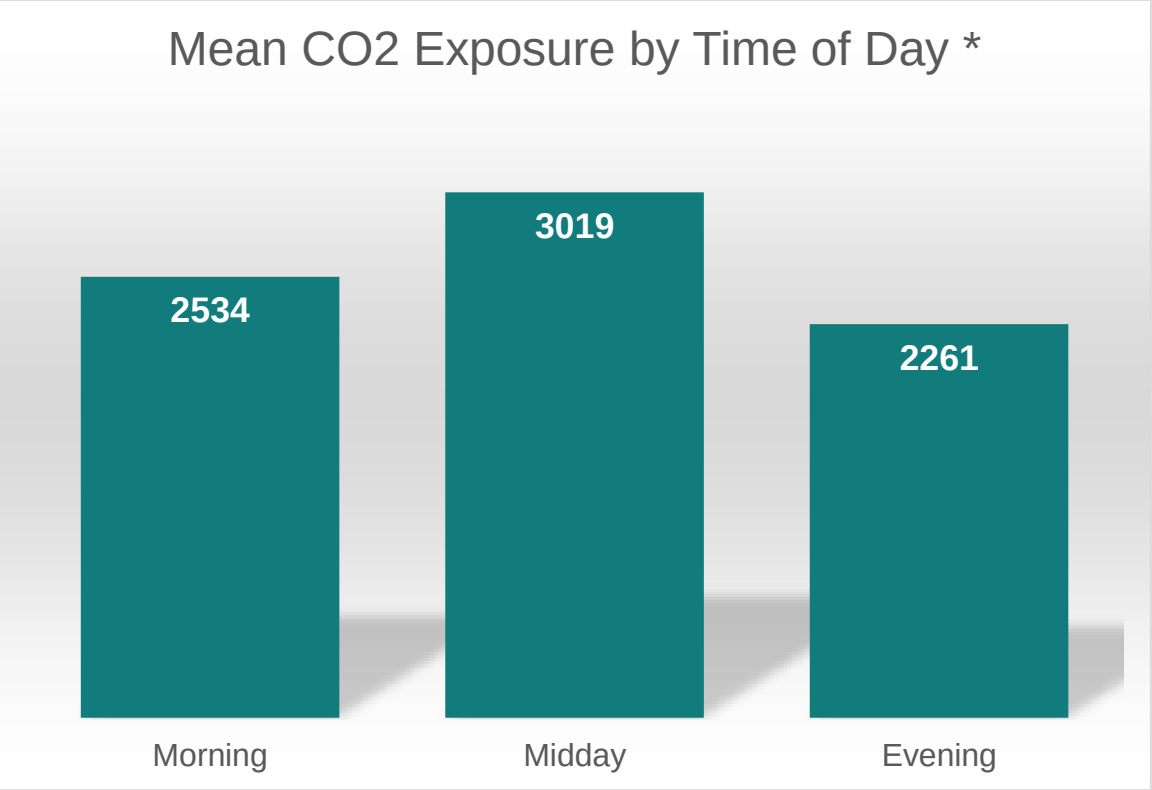


Overall CO2 Levels By Brewery Area

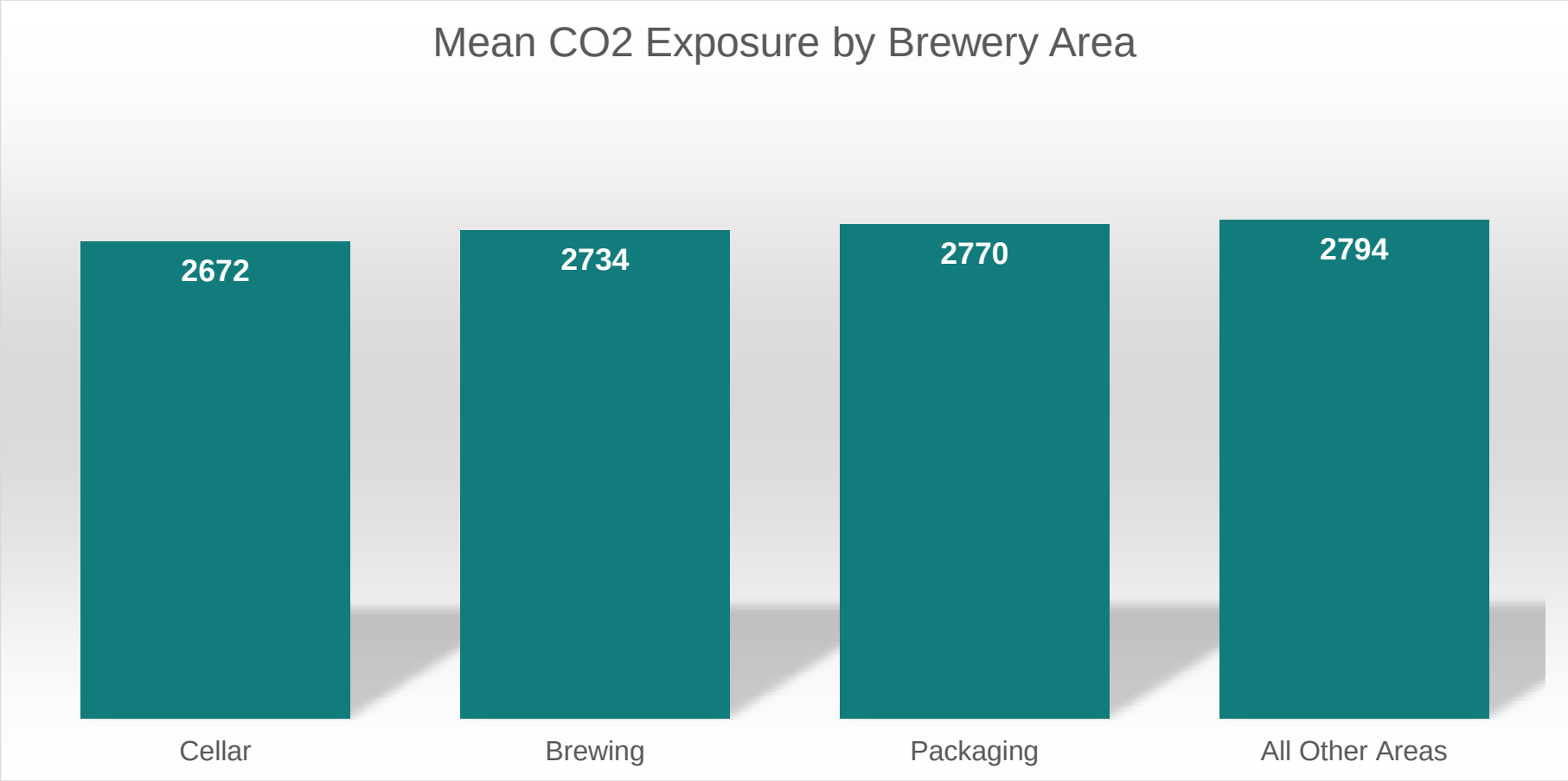


Small Brewery CO_2 Levels by Day and Time

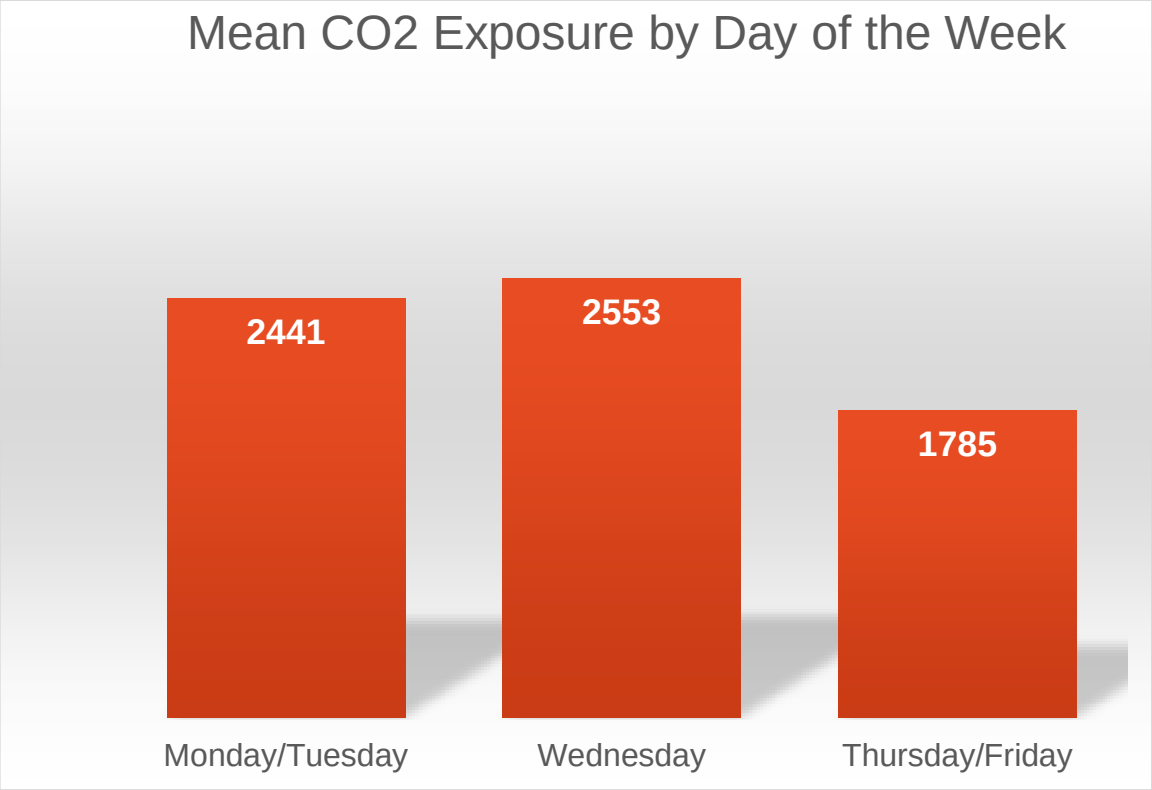


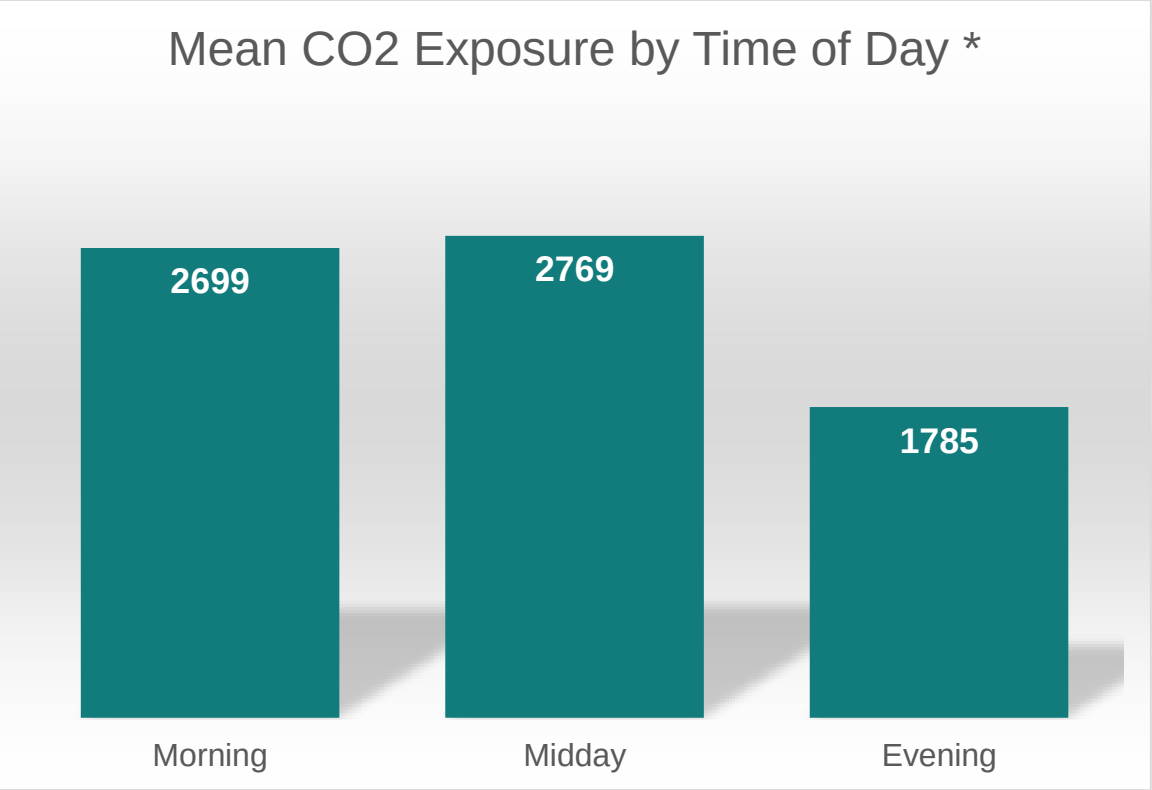


Small Brewery CO2 Levels By Brewery Area

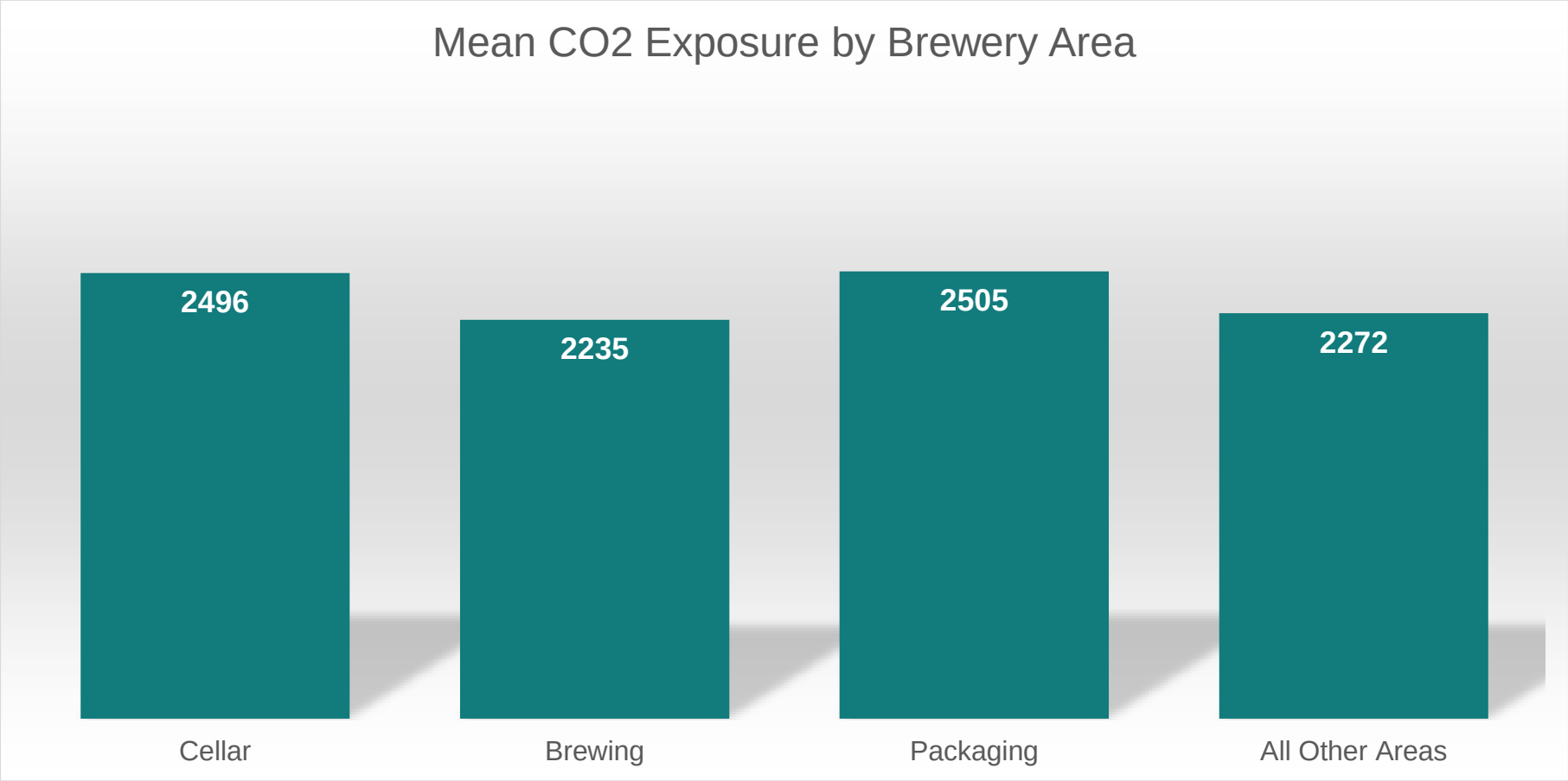


Medium Brewery CO_2 Levels by Day and Time

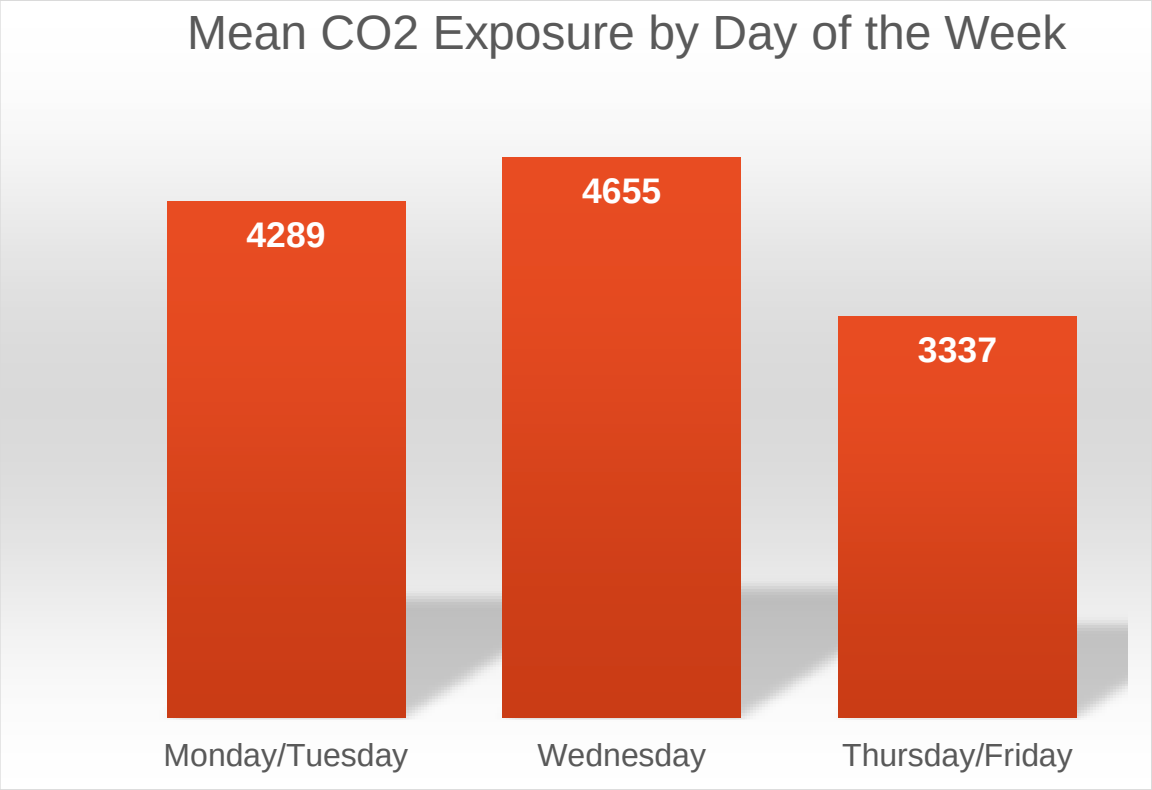


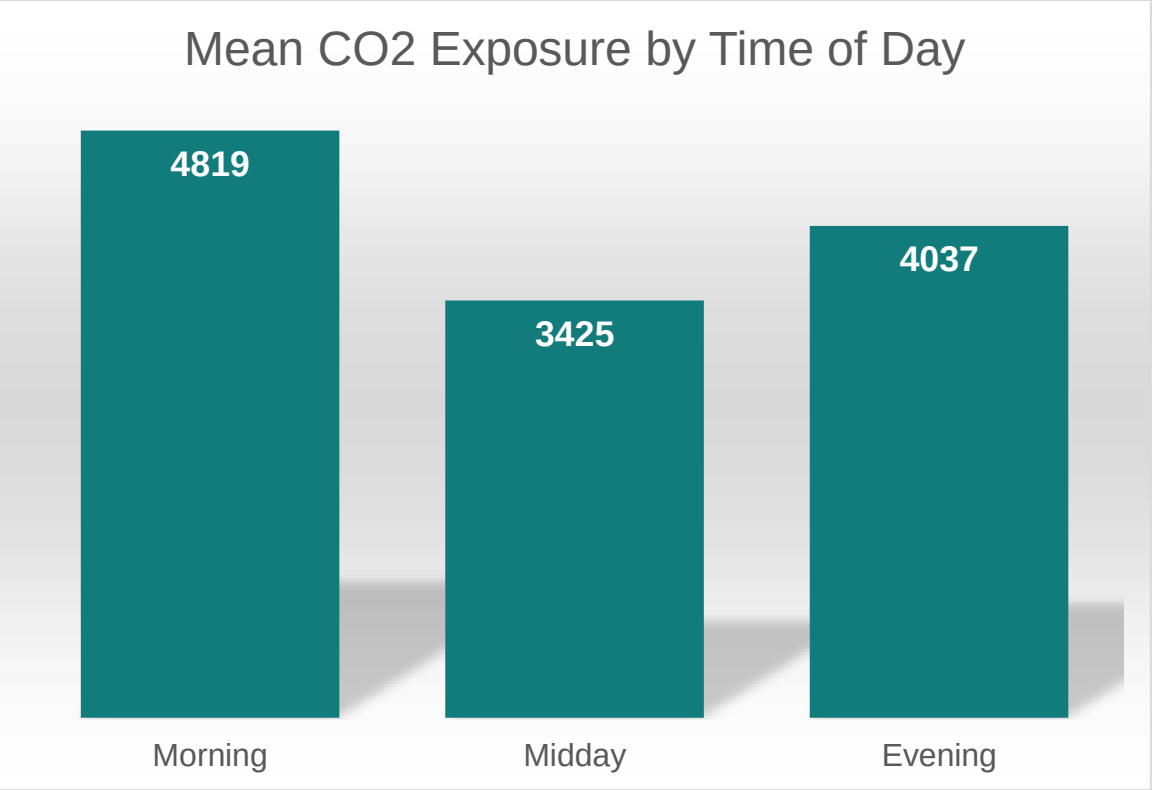


Medium Brewery CO2 Levels By Brewery Area

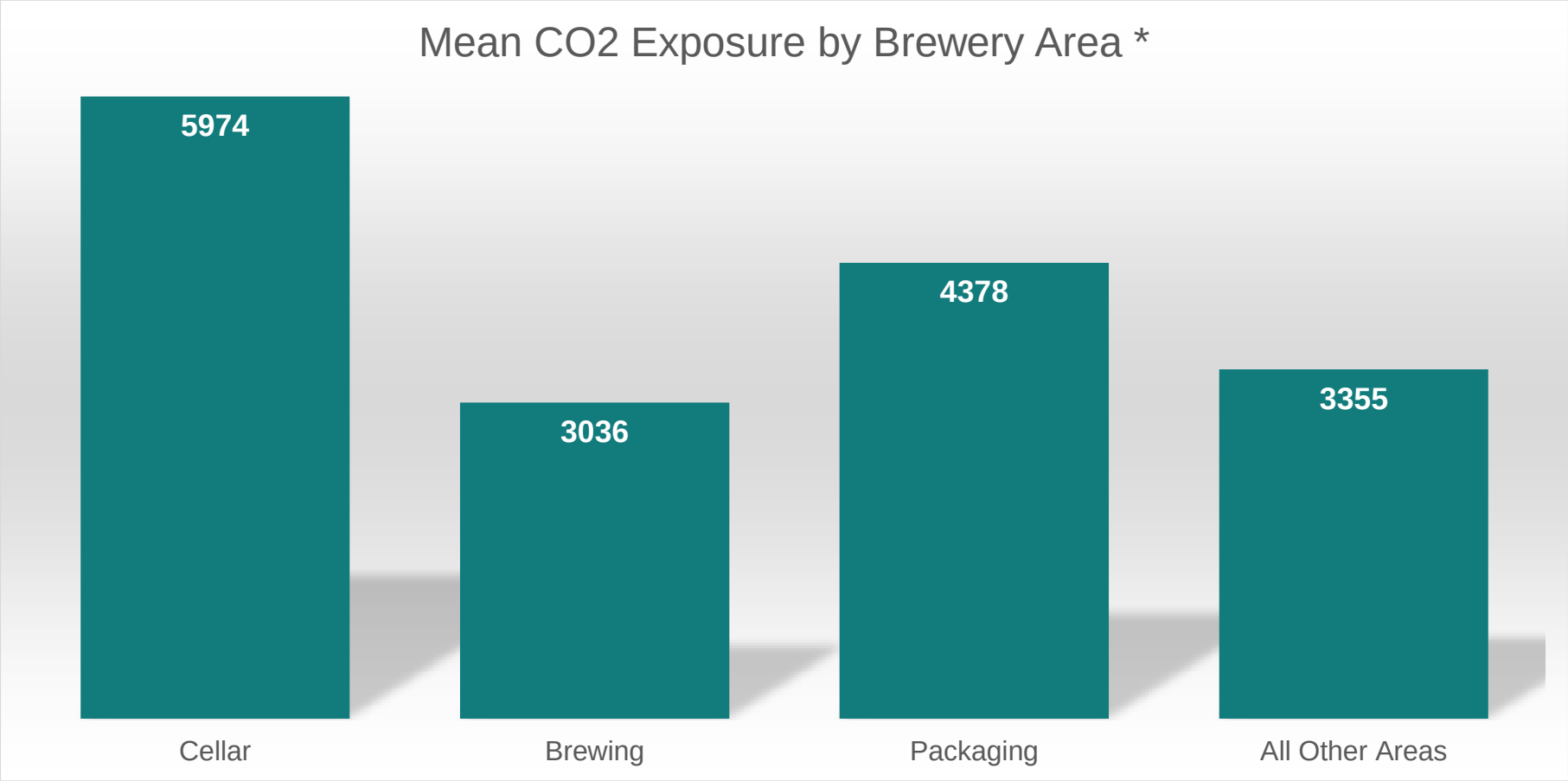


Large Brewery CO_2 Levels by Day and Time



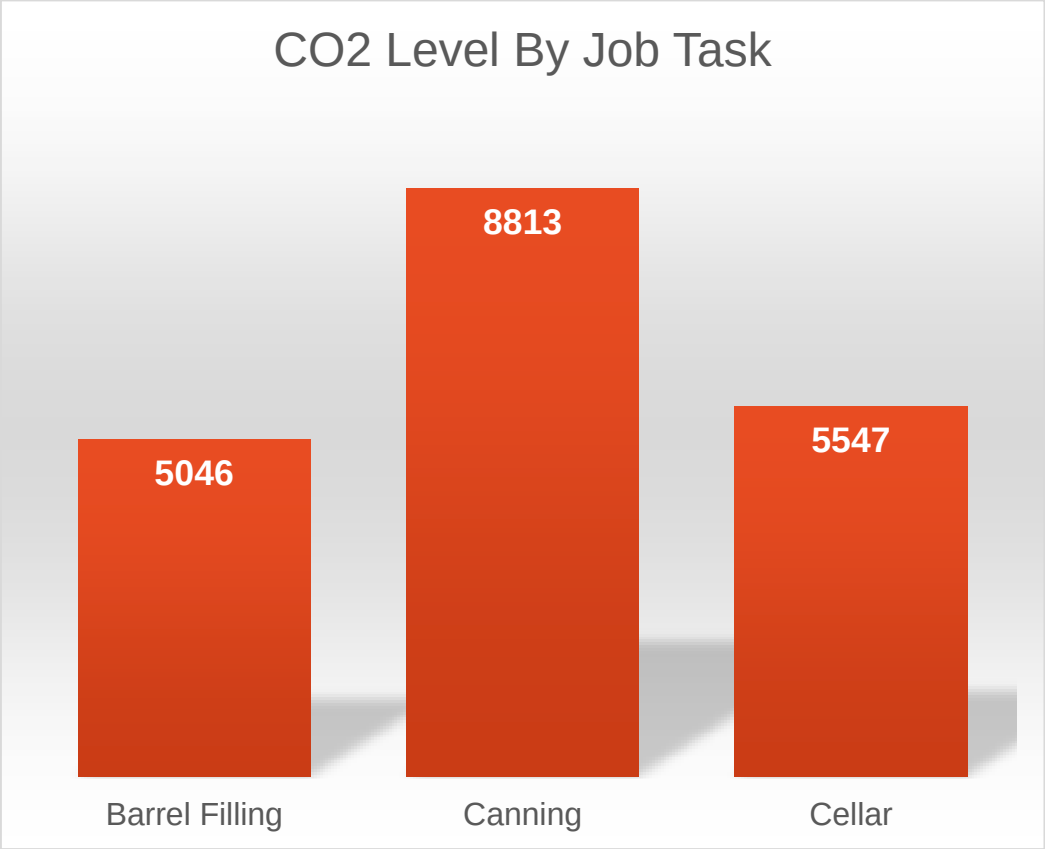


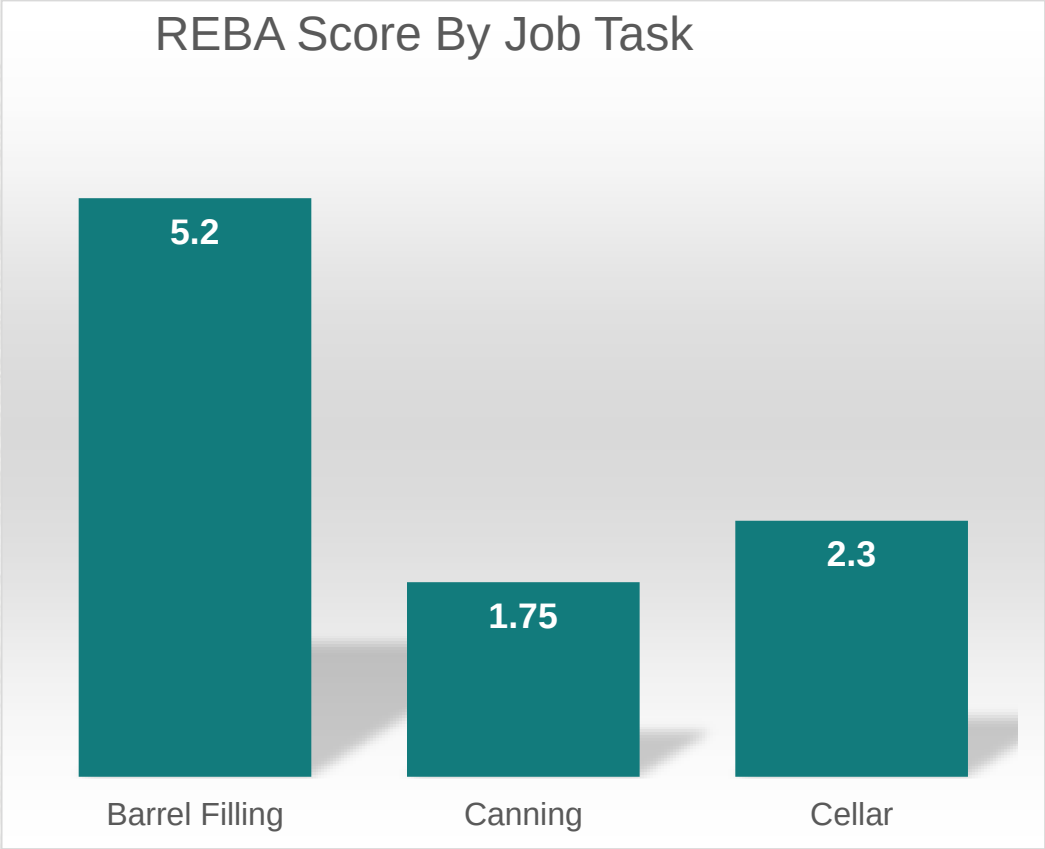
Large Brewery CO2 Levels By Brewery Area



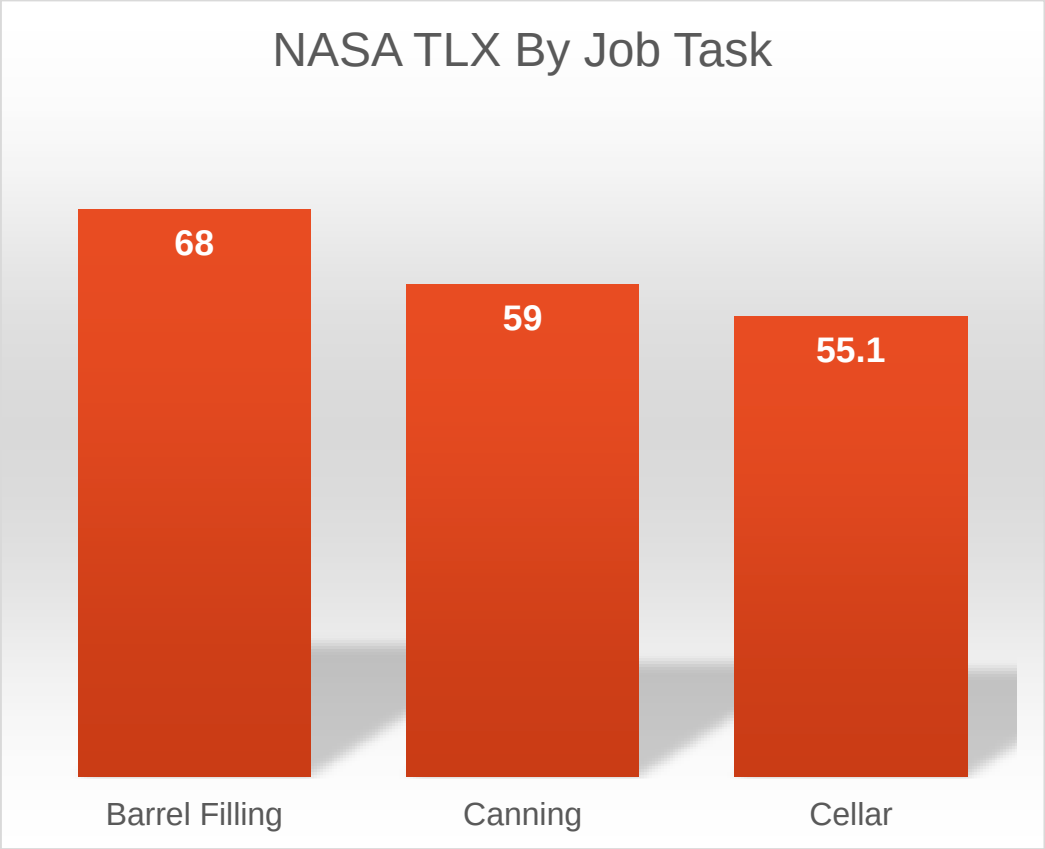
Phase 2 – Do Lower Levels of CO2 Effect a Brewer's Heart Rate

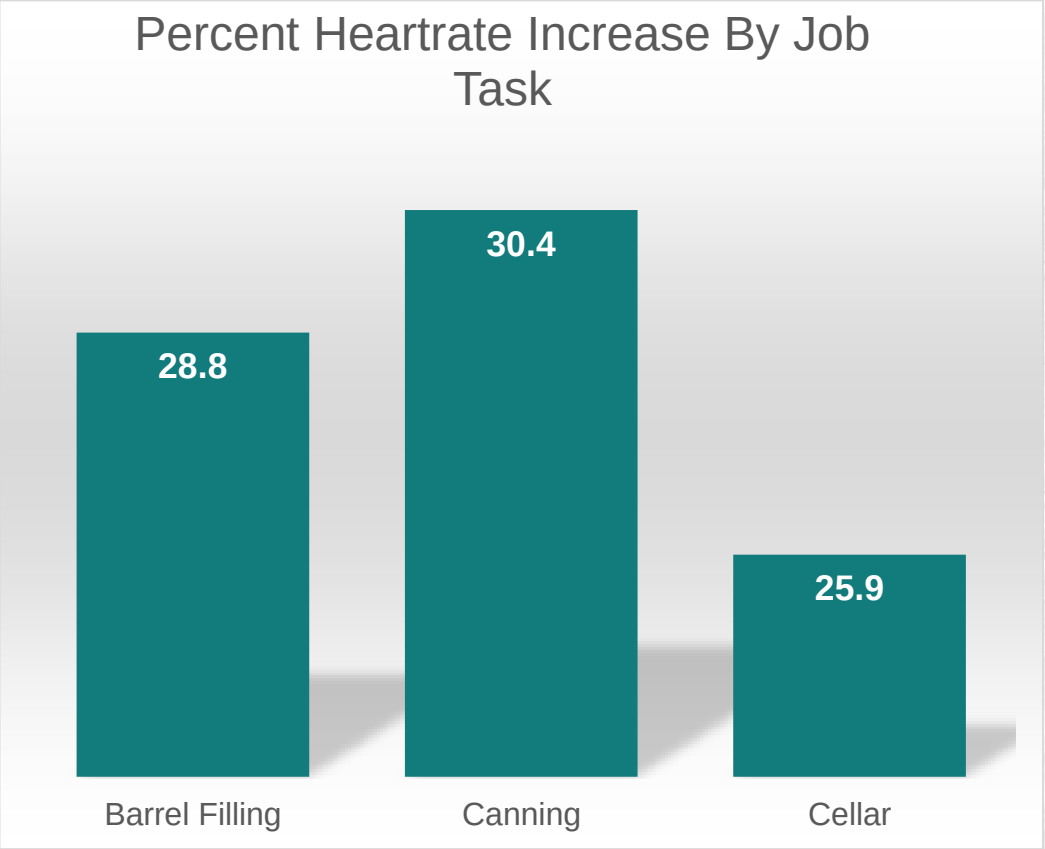
Brewery Mean CO2 Levels and REBA Score by Job Task



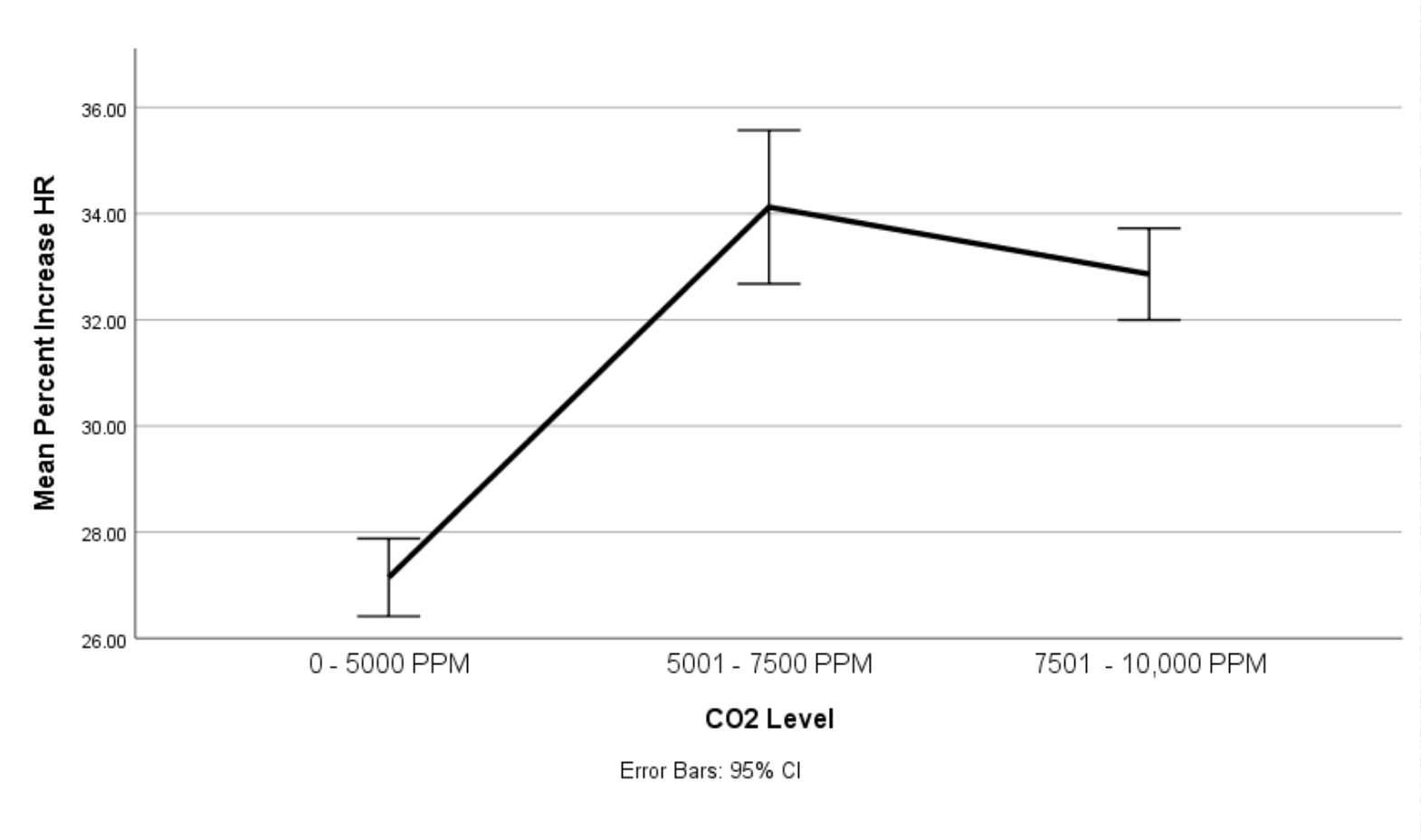


Brewery Mean CO2 Levels and REBA Score by Job Task

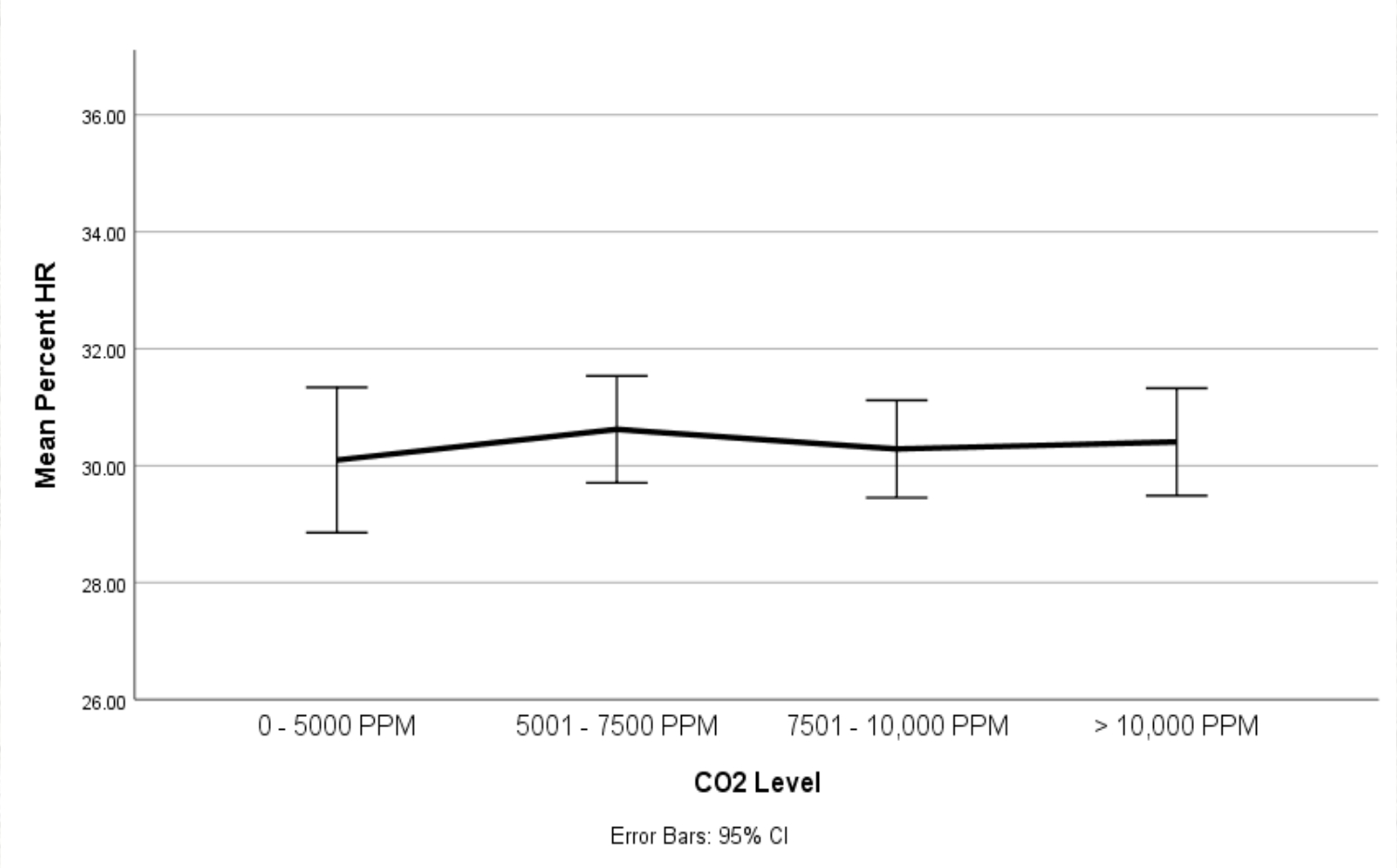




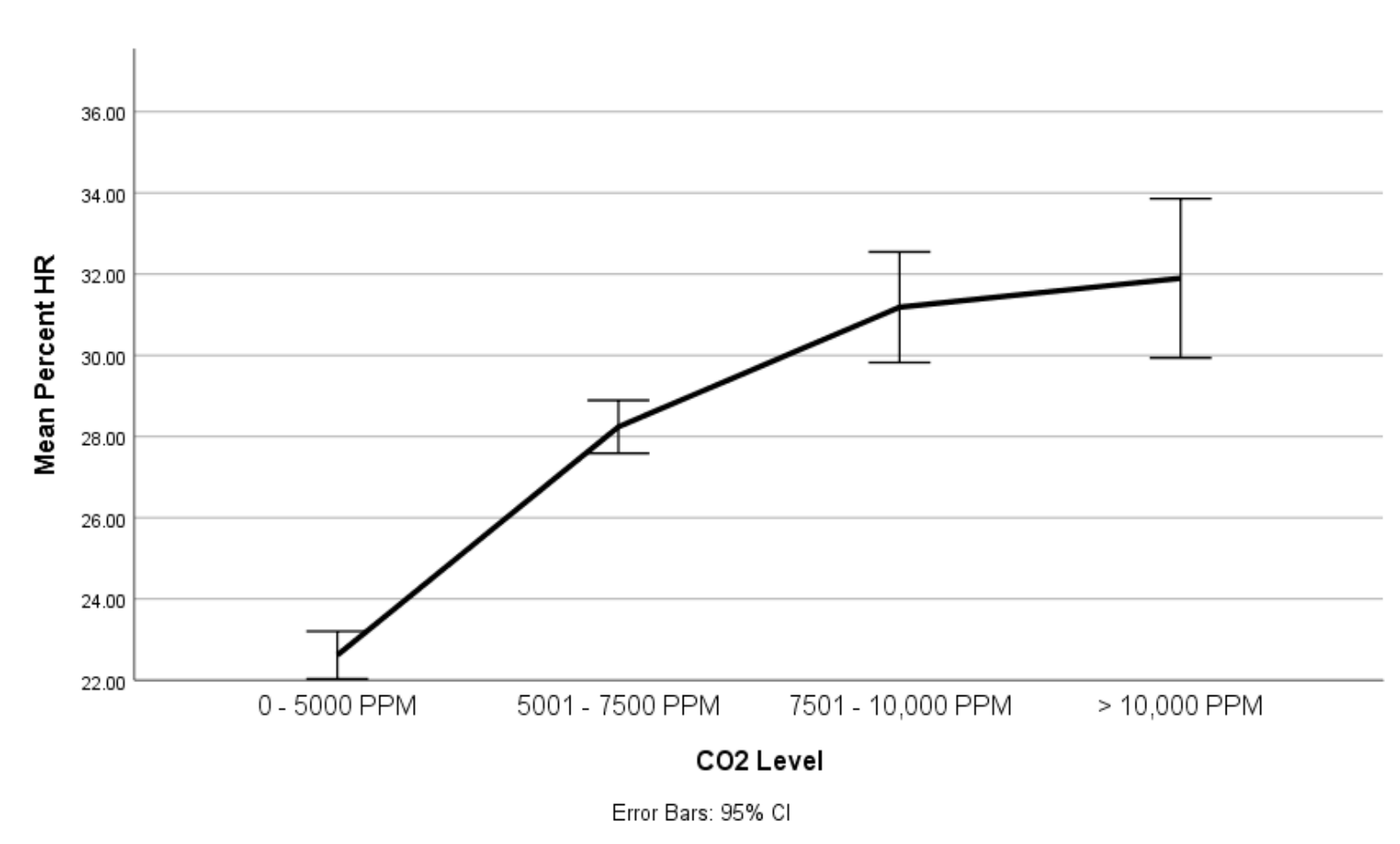
Barrel Filling Mean Percent Heart Rate increase By CO2 Concentration



Canning Mean Percent Heart Rate increase By CO2 Concentration



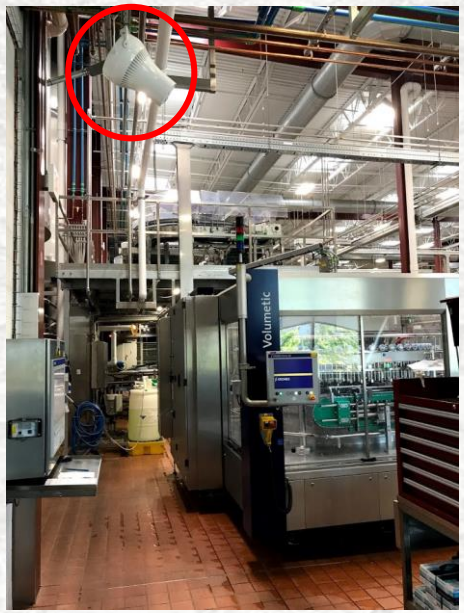
Cellar Mean Percent Heart Rate increase By CO2 Concentration



Phase 3 – Control Evaluation

Controls Implemented for Each Job Task Evaluated

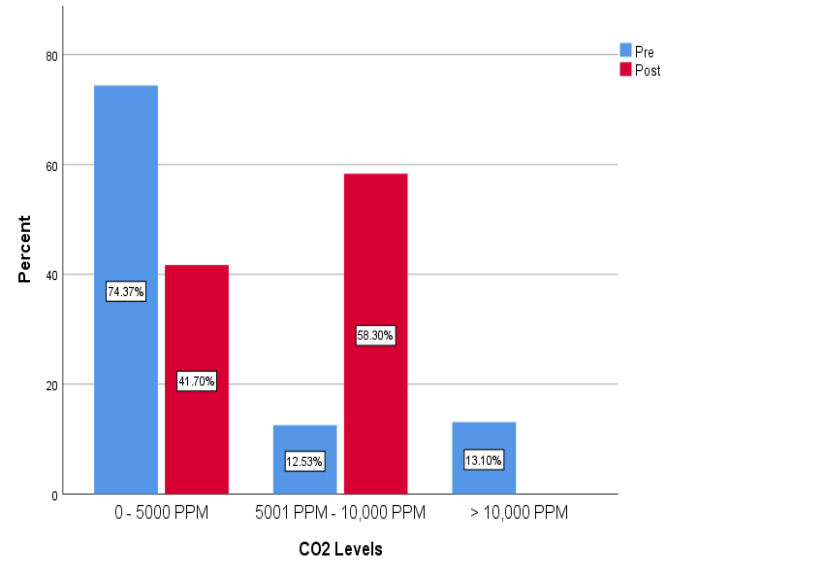
New Barrel Filler

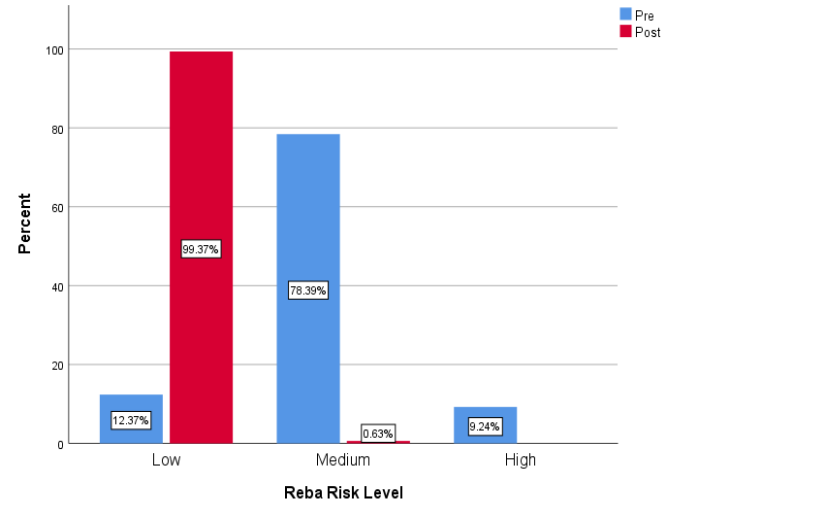


Canning Line
Dilution Ventilation

Cellar Extraction
Ventilation

Barrel Filling Control Evaluation

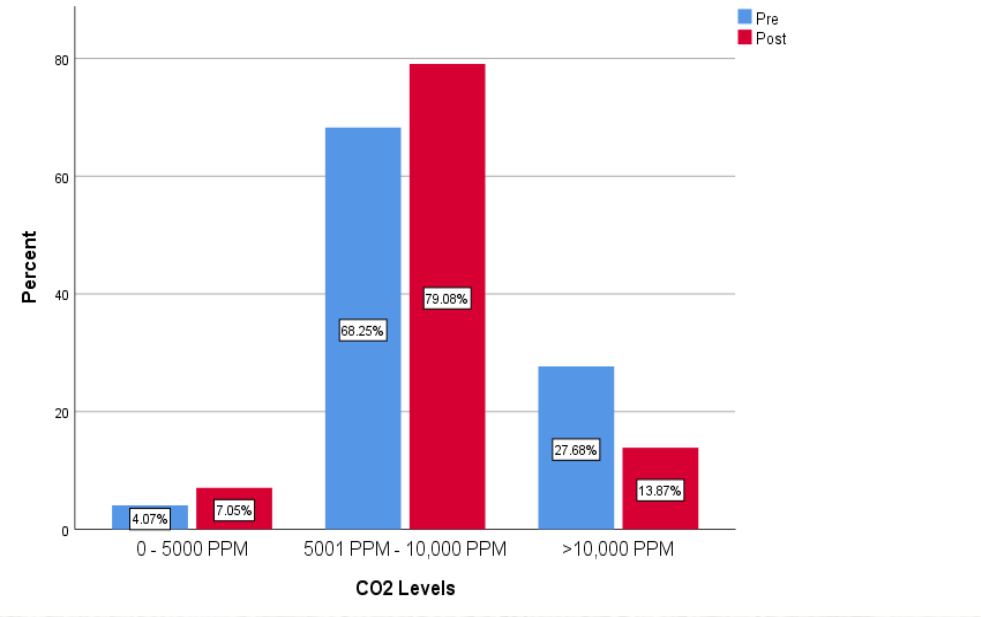


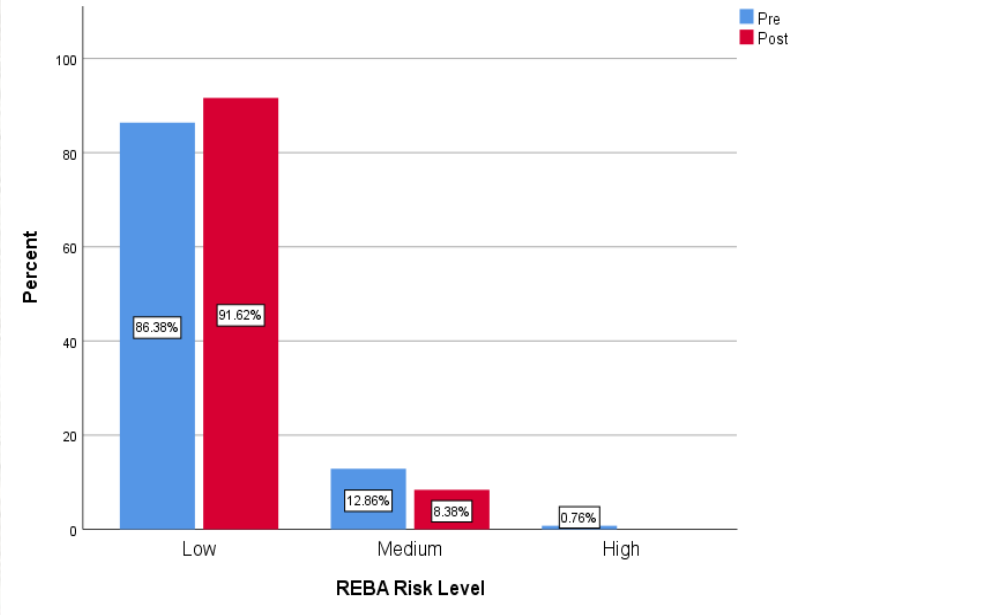


Barrel Filling Control Evaluation

	Pre Control n=250	Post-Control n=1162			
Variable	Mean	Mean	t	p	r
CO_2 Concentration	3927	5808	-22.51	< 0.001	0.79
Heart Rate	98.73	88.36	10.58	< 0.001	0.29
Percent Heart Rate Increase	32.75	24.82	11.21	< 0.001	0.49
REBA Score	5.057	1.687	50.17	< 0.001	0.93
NASA TLX	58.33	44.33	N/A	N/A	N/A

Canning Filler Control Evaluation

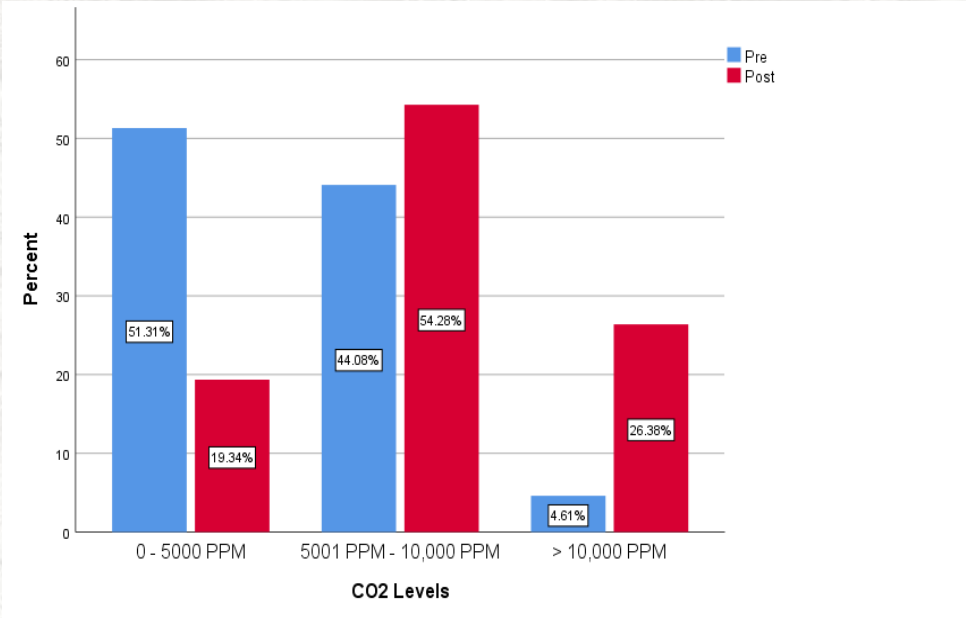


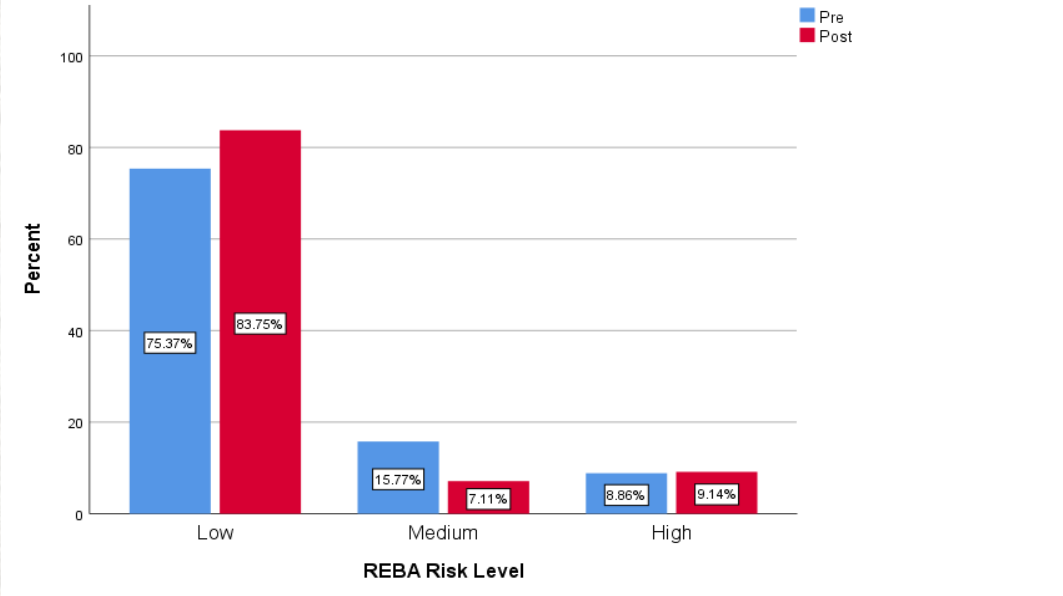


Canning Filler Control Evaluation

	Pre Control n = 656	Post-Control n = 929			
Variable	Mean	Mean	t	p	r
CO_2 Concentration	9273	7493	16.03	< 0.001	0.41
Heart Rate	104.0	92.42	22.33	< 0.001	0.55
Percent Heart Rate Increase	37.72	30.17	22.18	0.005	0.52
REBA Score	1.484	1.662	- 2.83	< 0.001	0.07
NASA TLX	50	50	N/A	N/A	N/A

Cellar Control Evaluation





Cellar Control Evaluation

	Pre Control n = 1338	Post-Control n = 1520			
Variable	Mean	Mean	t	p	r
CO_2 Concentration	5780	7783	-11.93	< 0.001	0.27
Heart Rate	90.09	86.80	8.595	< 0.001	0.16
Percent Heart Rate Increase	28.12	25.27	9.325	< 0.001	0.17
REBA Score	2.97	2.01	10.06	< 0.001	0.19
NASA TLX	60.67	55.67	N/A	N/A	N/A

Conclusions

Phase 1 – CO_2 Brewery Levels

Conclusions

- Levels of CO_2 in breweries can exceed legal and recommended exposure limits for 8 hours in large and mid-sized breweries.
- The cellar and packaging areas of a brewery are of most concern when addressing CO_2 exposures.
- The production cycle on a daily basis affects CO_2 levels in small and Mid-Sized Breweries
- The more areas are separated in a brewery the greater the CO_2 exposures.
- CO_2 exposure levels are dependent on square footage, Fermentation capacity, and production levels.

Workload, Biomechanical Stressors, and CO_2 Exposure Levels Effect on Heart Rate

Conclusions

- Workload had an impact on the barrel filling task (especially the physical demand subscale).
- Biomechanical stressors had the largest impact on heart rate in the barrel filling task.
- Rising Levels of CO_2 had the largest impact on heartrate in the cellar.
- Consistently high levels of CO_2 in the canning filler task had the largest impact on heart rate in any of the three job tasks evaluated.
- The exact contribution of each stressor on heart rate is unknown.

Effectiveness of Controls

Conclusions

- Ventilation and work station redesign can be effective in reducing heart rates in brewers to reduce fatigue.
- The redesign of tasks with high biomechanical stress makes a large impact on brewer's heart rate and fatigue
- Dilution ventilation is effective in areas where work stations are fixed.
- Dilution ventilation is limited by brewery ambient air concentrations
- Extraction ventilation has limitations in application

Effectiveness of Controls

Other Controls to Consider

- Push – Pull Ventilation
- Extraction and High Gravity Fermentations
- Piping CO_2 out of Building
- Dedicated line for Fermenter Evacuations
- CO2 recovery systems
- Raise items to move to waist level
- Eliminate reaching above shoulder level and away from your body

Acknowledgements

- Brewery Vivant – Grand Rapids
- Saugatuck Brewing – Douglas
- Founders Brewing Company – Grand Rapids
- Cody Green – Founders
- Dr. Jim McGlothlin and Kyle Fischer – VEM Systems Developers

Questions

Contact Information:

Dave Huizen

huizend@gvsu.edu

616-331-5596