

Yeast Flatulence or Eructation (CO₂):

What are the effects and
how to control It



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Yeast Flatulence or Eructation (CO₂):



Why this study?

- Tremendous growth in small brewing operations
- Safety and Health – An after thought?
- Little or no data on CO₂ exposures in breweries
- Little data on effects of CO₂ at levels < 10,000 PPM
- Curious on the impact of combined risk on health

Yeast Flatulence or Eructation (CO₂):

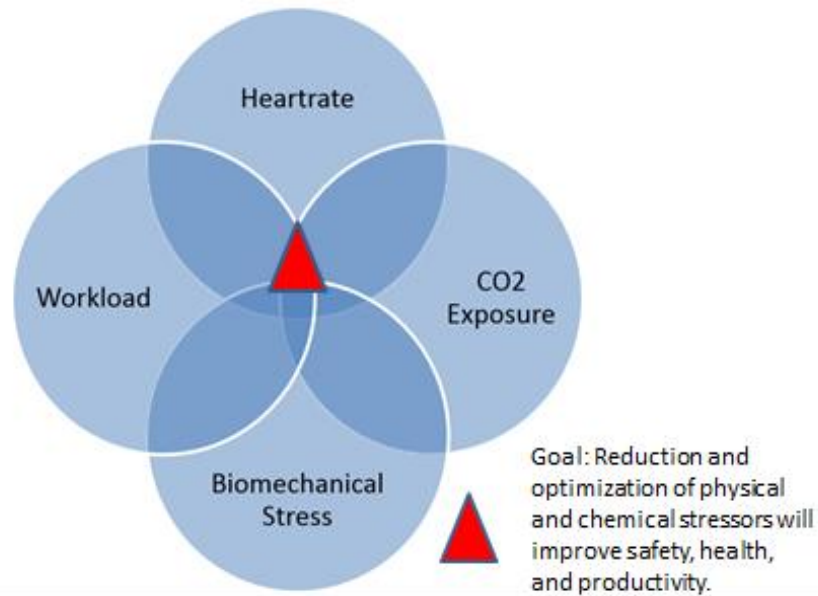


What are the takeaways of this presentation

- What is Combined Risk
- What CO₂ levels are found in different sized breweries
- What variables can impact those CO₂ levels
- What effect do lower CO₂ levels have on heart rate
- What are effective control measures to reduce combined exposure

Combined Risk Exposure

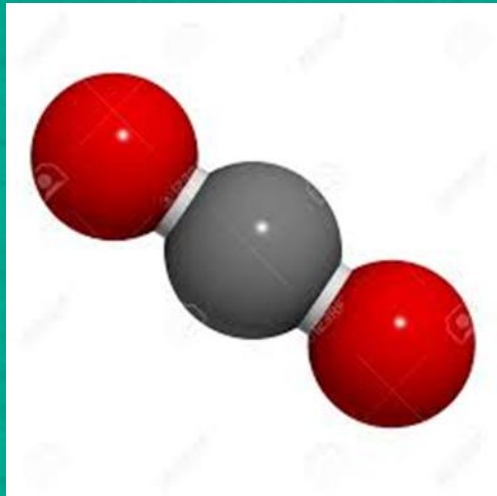
Yeast Flatulence or Eructation (CO₂):



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 CO₂

- Odorless – acidic smell at high concentrations (carbonic acid formation)
- Colorless
- Slightly pungent acid taste
- Non-flammable
- Density – 1.98 kgs/m³ -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 CO₂

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 CO₂

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

Health Effects of Workload

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

Risk #3 Workload



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
 - Garmin VIRB
- CO₂ 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



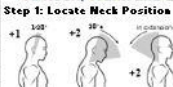
Biomechanical Risk Factor

- Rapid Entire Body Assessment - REBA

REBA Employee Assessment Worksheet Permission granted by Dr Lynn McAnastomy to convert the paper based format to an Excel spreadsheet version.

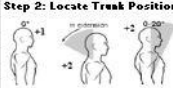
A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position




Step 1a: Adjust...
If neck is twisted: +1
If neck is side bending: +1

Step 2: Locate Trunk Position



Step 2a: Adjust...
If trunk is twisted: +1
If trunk is side bending: +1

Step 3: Legs



Adjust: 30-60° +1, 60° +2, 90° +3, 120° +4

Step 4: Look-up Posture Score in Table A
Using values from steps 1-3 above, locate score in Table A.

Step 5: Add Force/Load Score
If Load < 5kg: +0
If Load is 5 to 10kg: +1
If Load > 22lbs: +2
Adjust: If shock or rapid build up of force: add +1

Step 6: Score A, Find Row in Table C
Add values from steps 4 & 5 to obtain Score A.
Find row in Table C.

Table A

	1	2	3	4	5	6	7	8	9	10	11	12
Legs	1	2	3	4	1	2	3	4	1	2	3	4
Trunk Posture Score	1	2	3	4	1	2	3	4	1	2	3	4
Neck	1	2	3	4	1	2	3	4	1	2	3	4
Force/Load Score	1	2	3	4	1	2	3	4	1	2	3	4

Score A: 8

Table B

	1	2	3	4	5	6	7	8	9	10	11	12
Lower Arm	1	2	3	4	1	2	3	4	1	2	3	4
Wrist	1	2	3	4	1	2	3	4	1	2	3	4
Upper Arm	1	2	3	4	1	2	3	4	1	2	3	4
Trunk	1	2	3	4	1	2	3	4	1	2	3	4
Legs	1	2	3	4	1	2	3	4	1	2	3	4
Neck	1	2	3	4	1	2	3	4	1	2	3	4
Force/Load Score	1	2	3	4	1	2	3	4	1	2	3	4

Score B: 2

Table C


Score A (score from table A + load force score)	Score B, (table B value + coupling score)											
1	1	2	3	4	5	6	7	8	9	10	11	12
2	1	2	3	4	5	6	7	8	9	10	11	12
3	2	3	3	3	4	5	6	7	8	9	10	11
4	4	3	4	4	4	5	6	7	8	9	10	10
5	4	4	4	4	5	6	7	8	8	9	9	9
6	6	6	6	6	7	8	8	9	9	10	10	10
7	7	7	7	7	8	9	9	10	10	11	11	11
8	8	8	8	8	9	10	10	10	10	11	11	11
9	9	9	9	9	10	10	10	11	11	12	12	12
10	10	10	10	10	11	11	11	12	12	12	12	12
11	11	11	11	11	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

Table C Score: 8 + **Activity Score**: 2 = **Final REBA Score**: 10

Scoring:
1 = Negligible risk
2 or 3 = low risk, change may be needed
4 to 7 = medium risk, further investigation, change soon
8 to 10 = high risk, investigate & implement change
11+ = very high risk, implement change


B: Arms and Wrist Analysis

Step 7: Locate Upper Arm Position:




Step 7a: Adjust...
If shoulder is raised: +1
If Upper Arm is abducted: +1
If arm is supported or leaning: -1

Step 8: Locate Lower Arm Position:



Step 8a: Adjust...
If wrist is bent from midline or twisted: Add +1

Step 9: Locate Wrist Position:



Step 9a: Adjust...
If wrist is bent from midline or twisted: Add +1

Step 10: Look-up Posture Score in Table B:
Using values from steps 7-9 above, locate score in Table B.

Step 11: Add Coupling Score
Well fitted handles and mid range power grip, good: +0
Acceptable but not ideal hold or coupling acceptable with another body part, fair: +1
Hand hold not acceptable but possible, poor: +2
No handles, awkward, unsafe with any body part, unacceptable: +3

Step 12: Score B, Find column in Table C
Add values from steps 10 & 11 to obtain Score B. Find Column in Table C and match with Score A row from step 6 to obtain Table C score.

Step 13: Activity Score
+1 or more body parts are held longer than a minute (static)
+1 Repeated small range actions (more than 4x per minute)
+1 Action causes rapid large range change in postures or unstable base

Methodology: Workload



NASA – Task Load Index (TLX)

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 performing 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) to accomplish 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
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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 were you?

Very Low Very High

Results

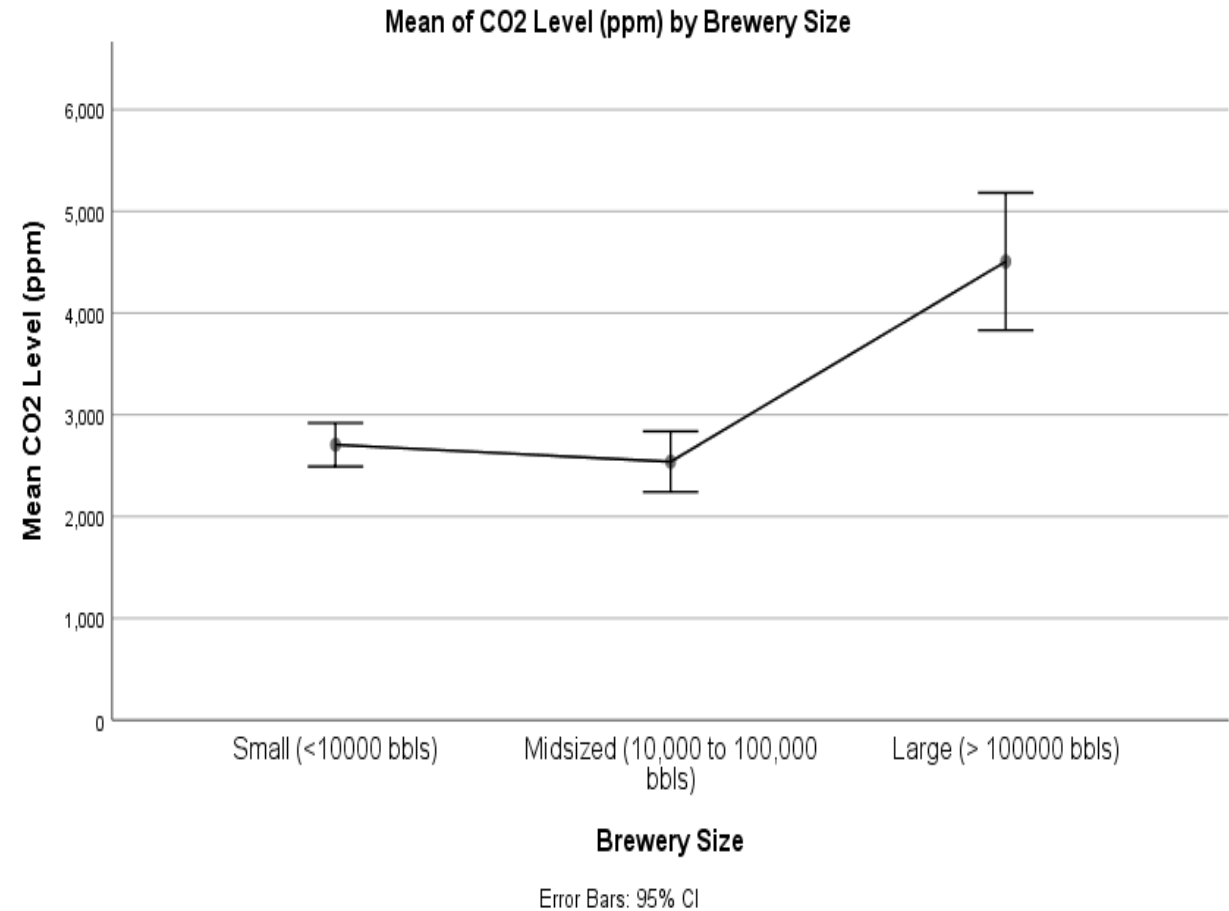
Phase 1 – What Are the CO₂ Levels Found in Different Sized Breweries

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

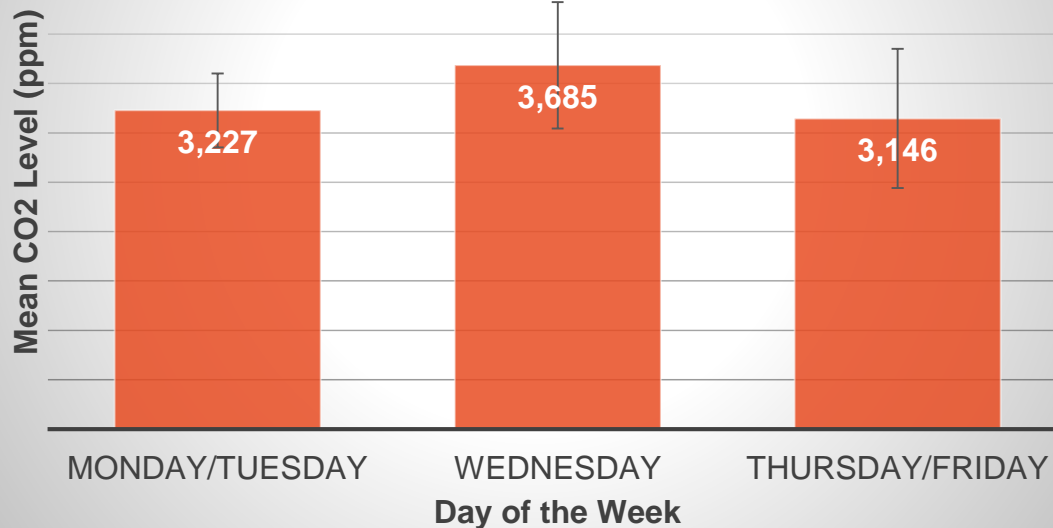
Overall CO₂ Level In Craft Breweries by Size

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

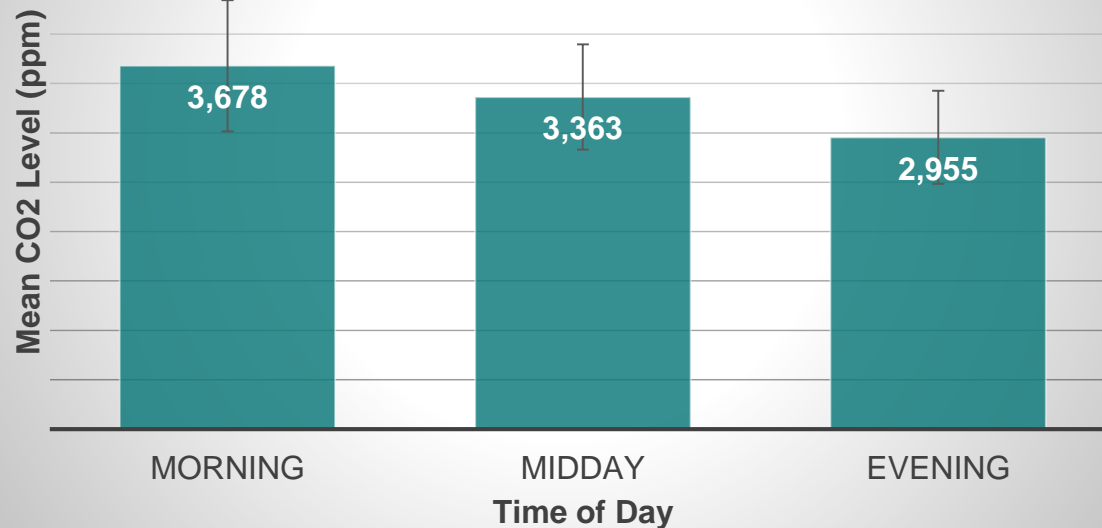


Overall CO₂ Levels by Day and Time

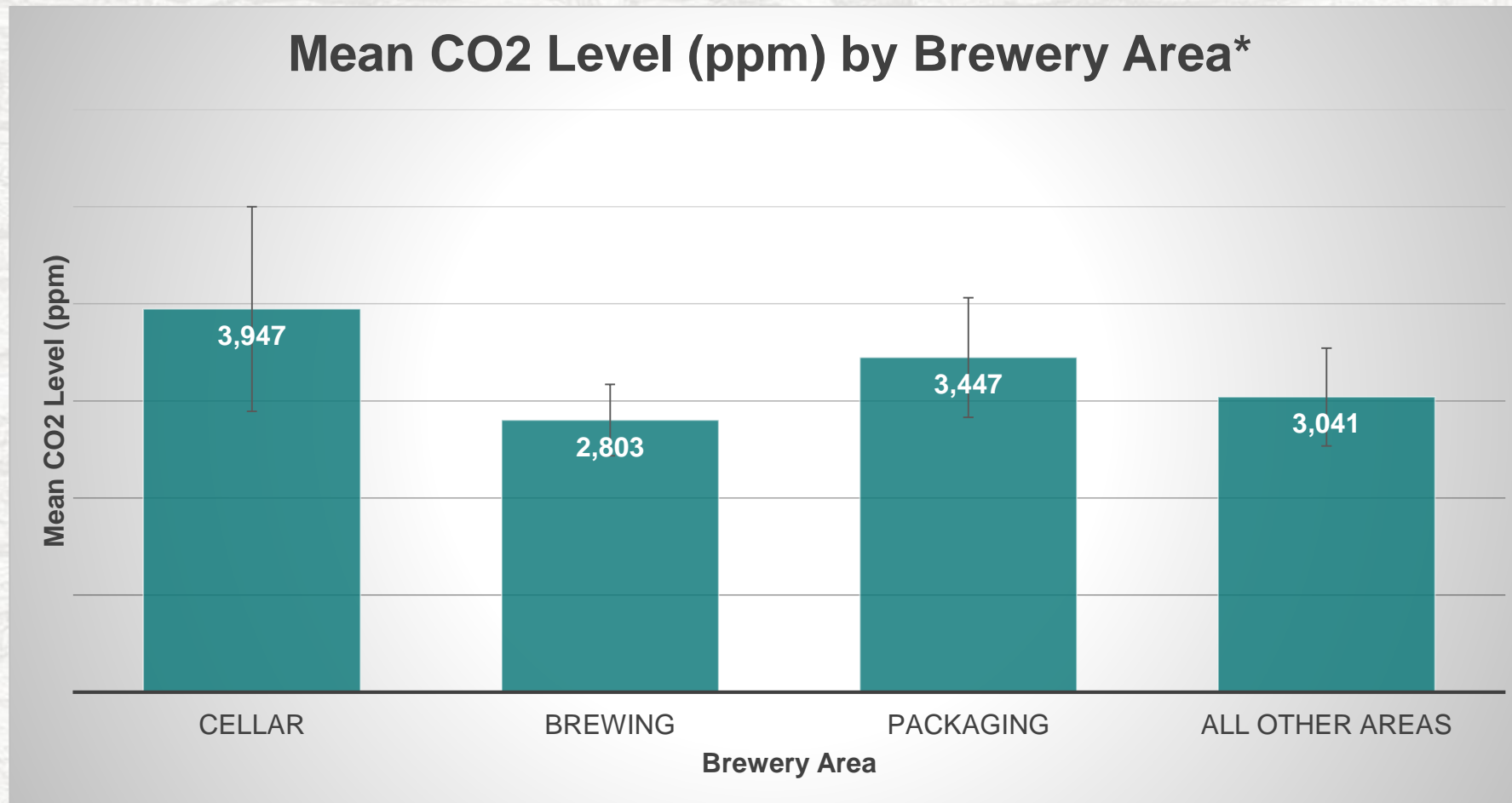
Mean CO₂ Level (ppm) by Day of the Week



Mean CO₂ Level (ppm) by Time of Day

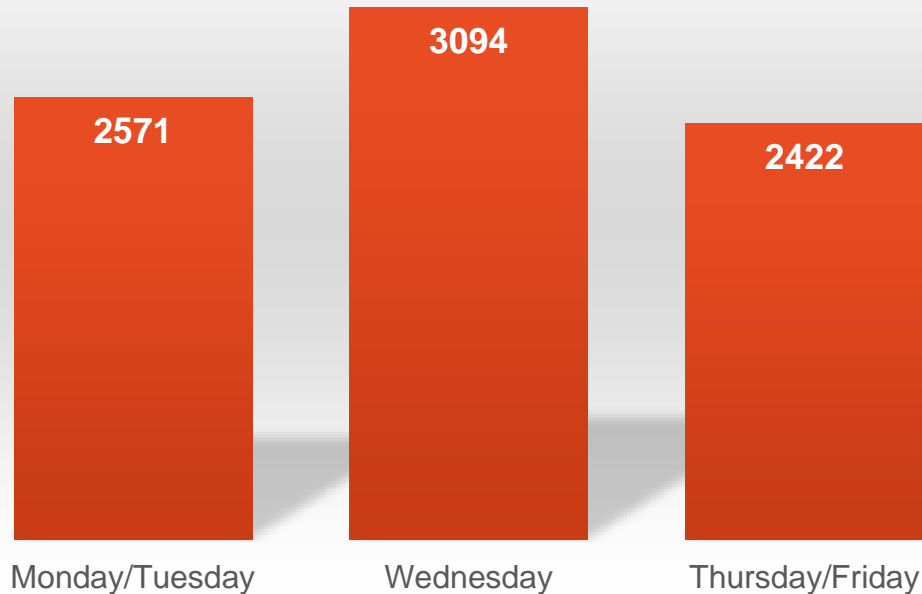


Overall CO2 Levels By Brewery Area

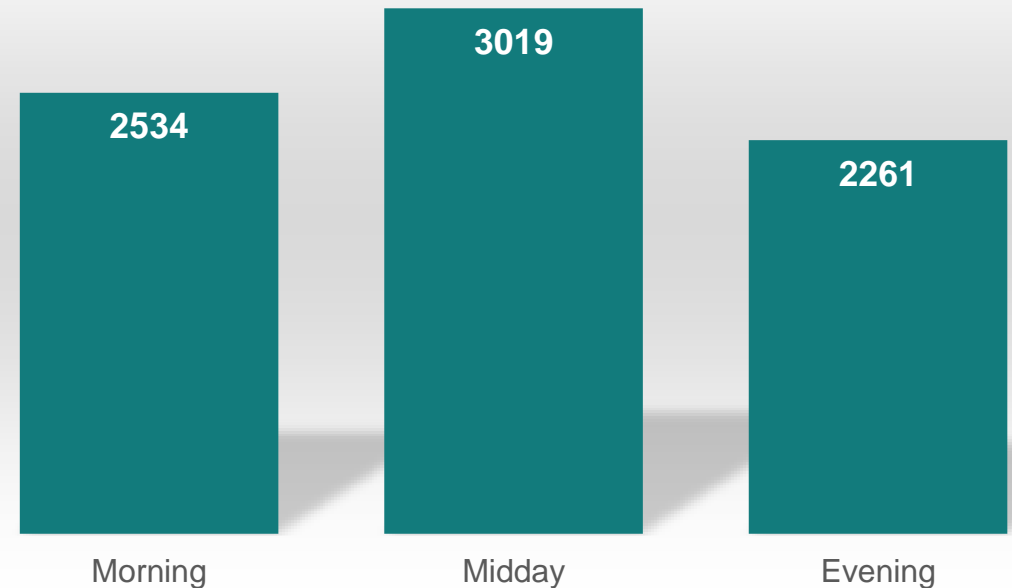


Small Brewery CO₂ Levels by Day and Time

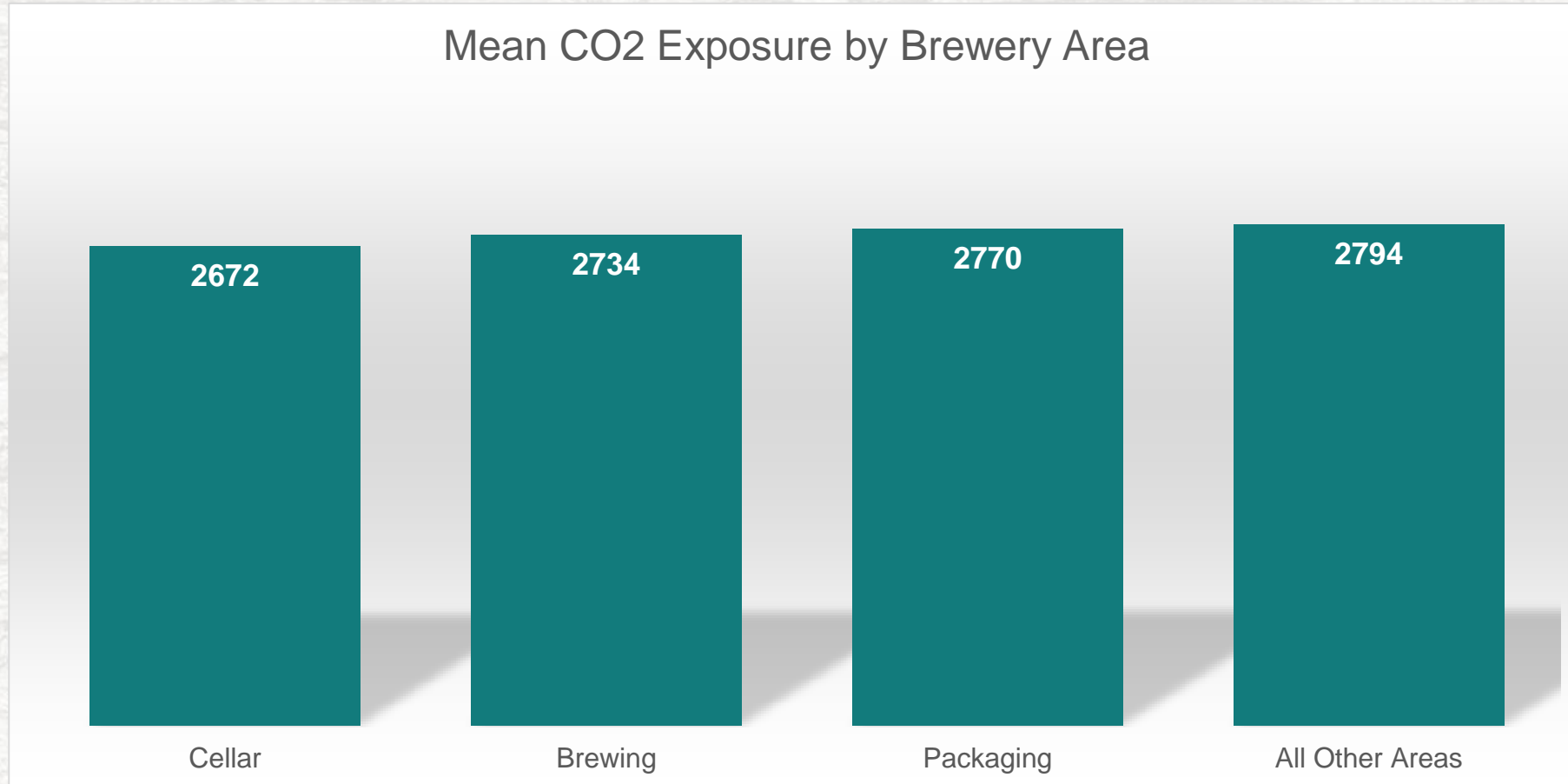
Mean CO2 Exposure by Day of the Week



Mean CO2 Exposure by Time of Day *

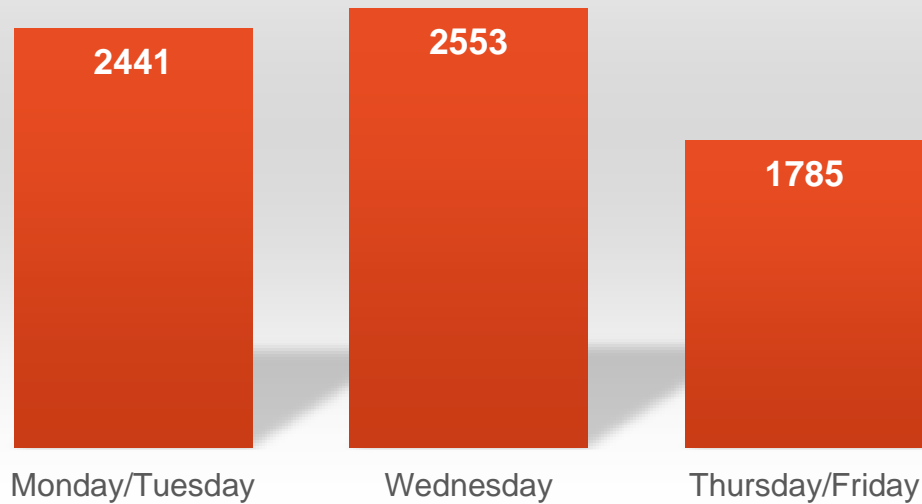


Small Brewery CO2 Levels By Brewery Area

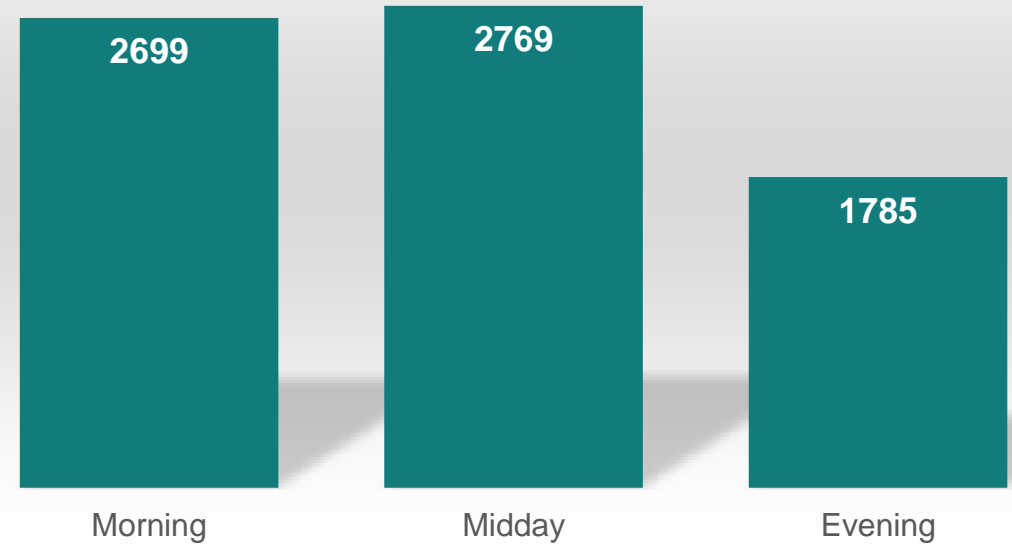


Medium Brewery CO₂ Levels by Day and Time

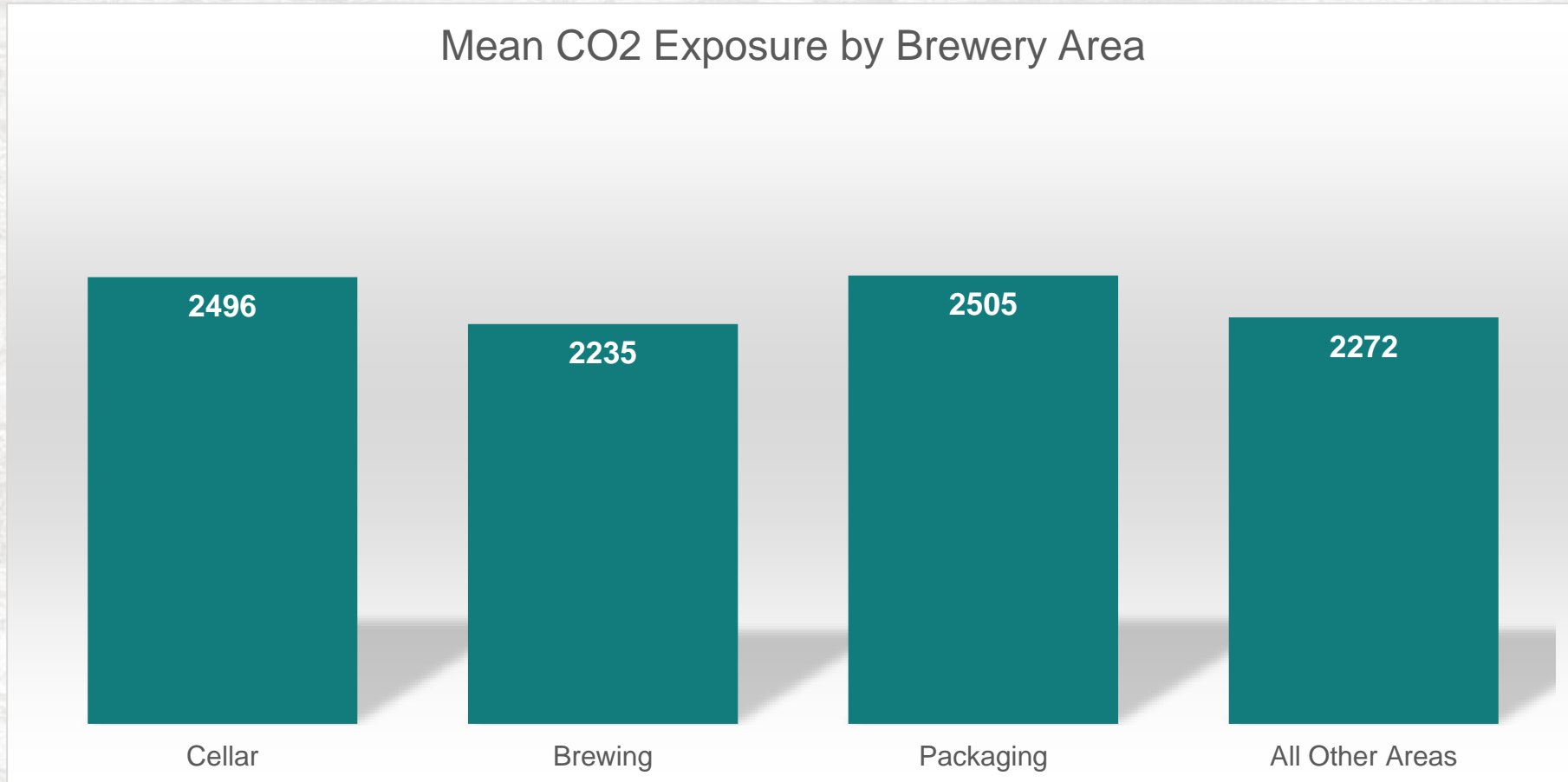
Mean CO2 Exposure by Day of the Week



Mean CO2 Exposure by Time of Day *

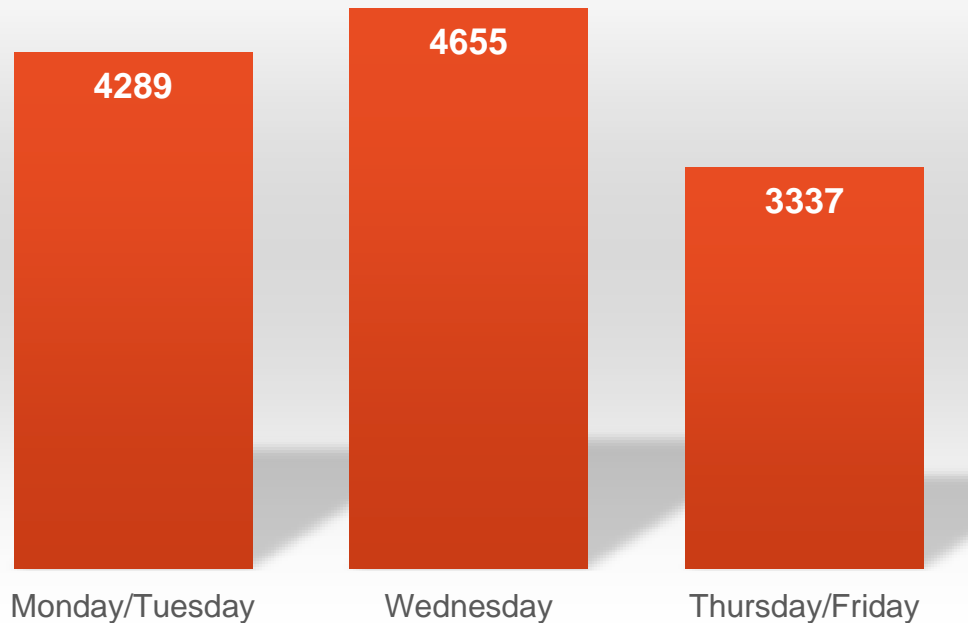


Medium Brewery CO2 Levels By Brewery Area

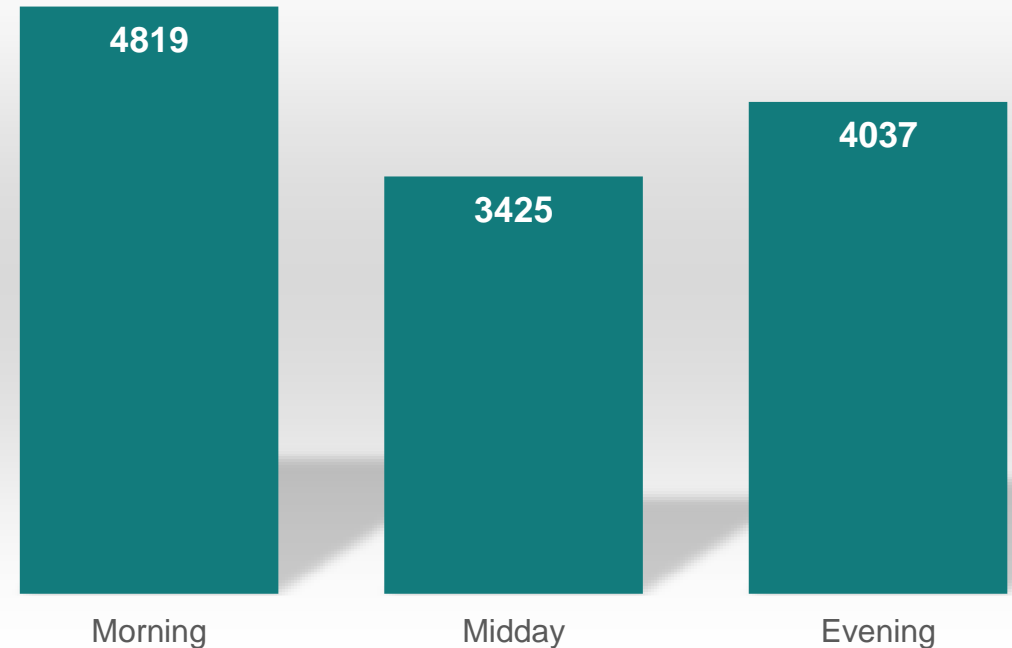


Large Brewery CO₂ Levels by Day and Time

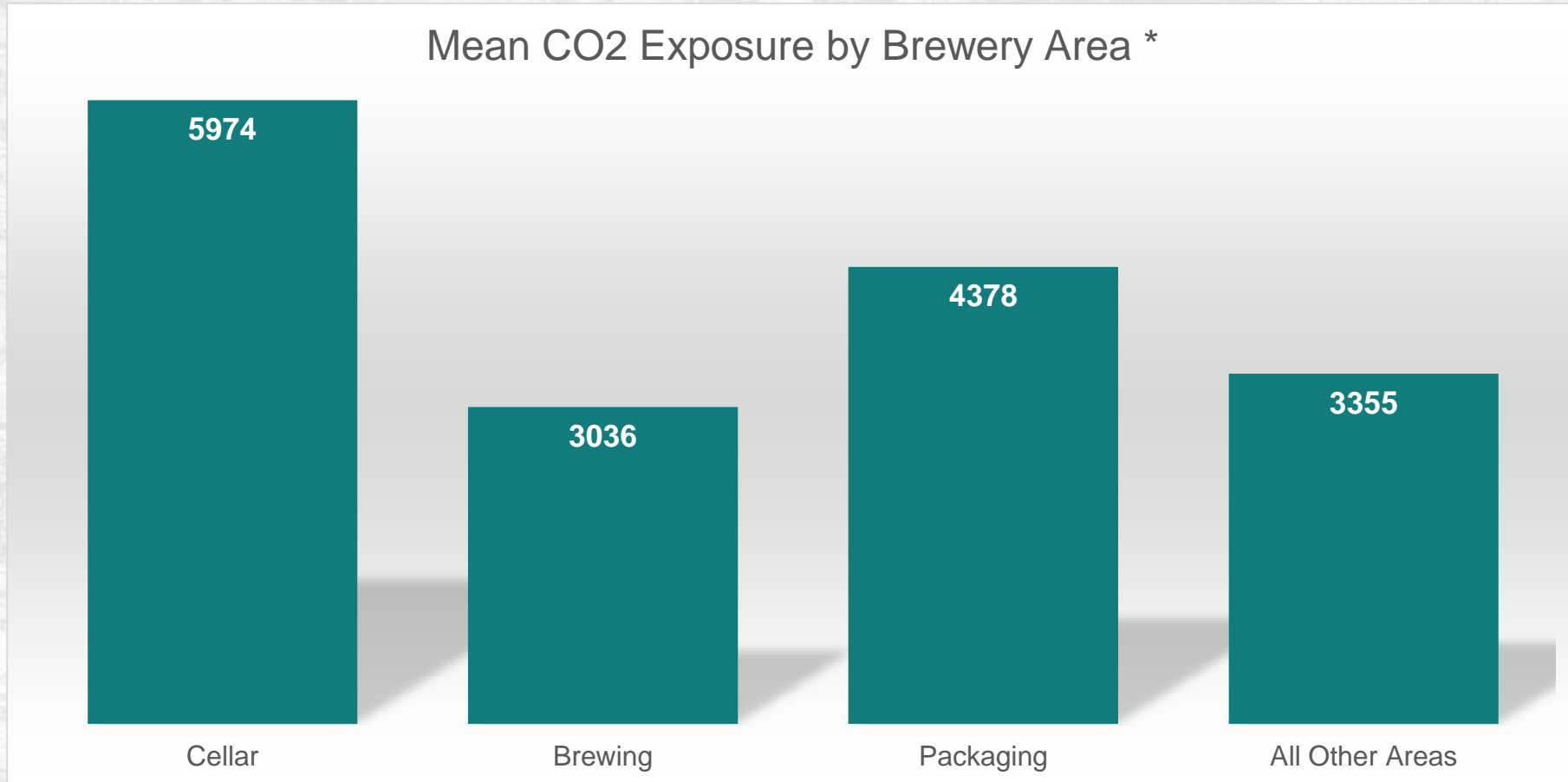
Mean CO₂ Exposure by Day of the Week



Mean CO₂ Exposure by Time of Day



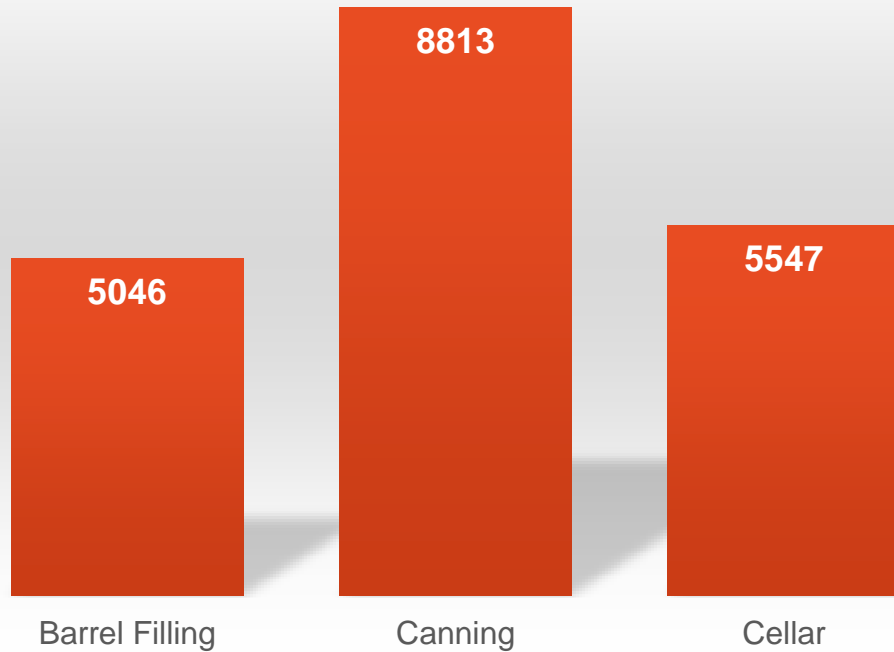
Large Brewery CO2 Levels By Brewery Area



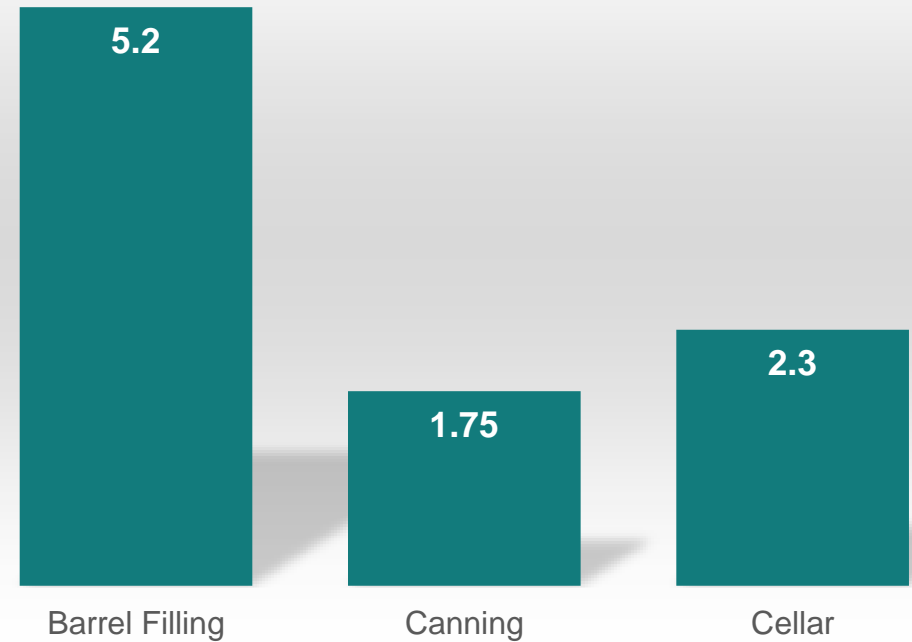
Phase 2 – Do Lower Levels of CO2 Effect a Brewer's Heart Rate

Brewery Mean CO2 Levels and REBA Score by Job Task

CO2 Level By Job Task

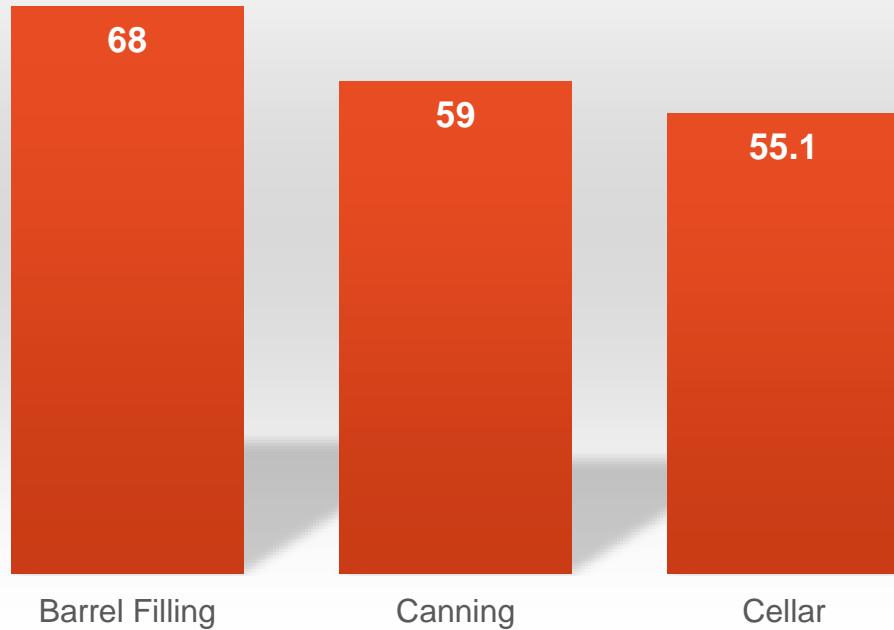


REBA Score By Job Task

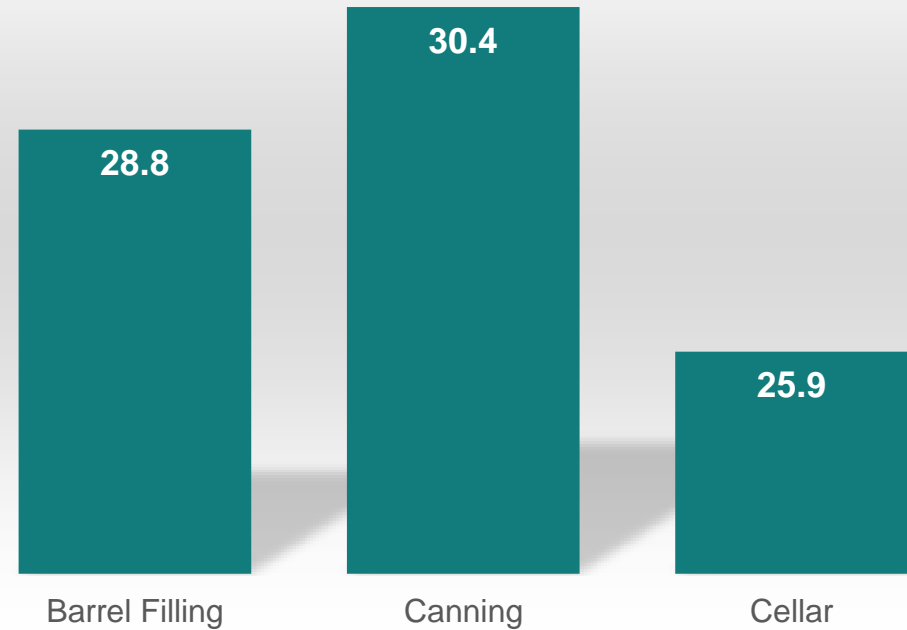


Brewery Mean CO2 Levels and REBA Score by Job Task

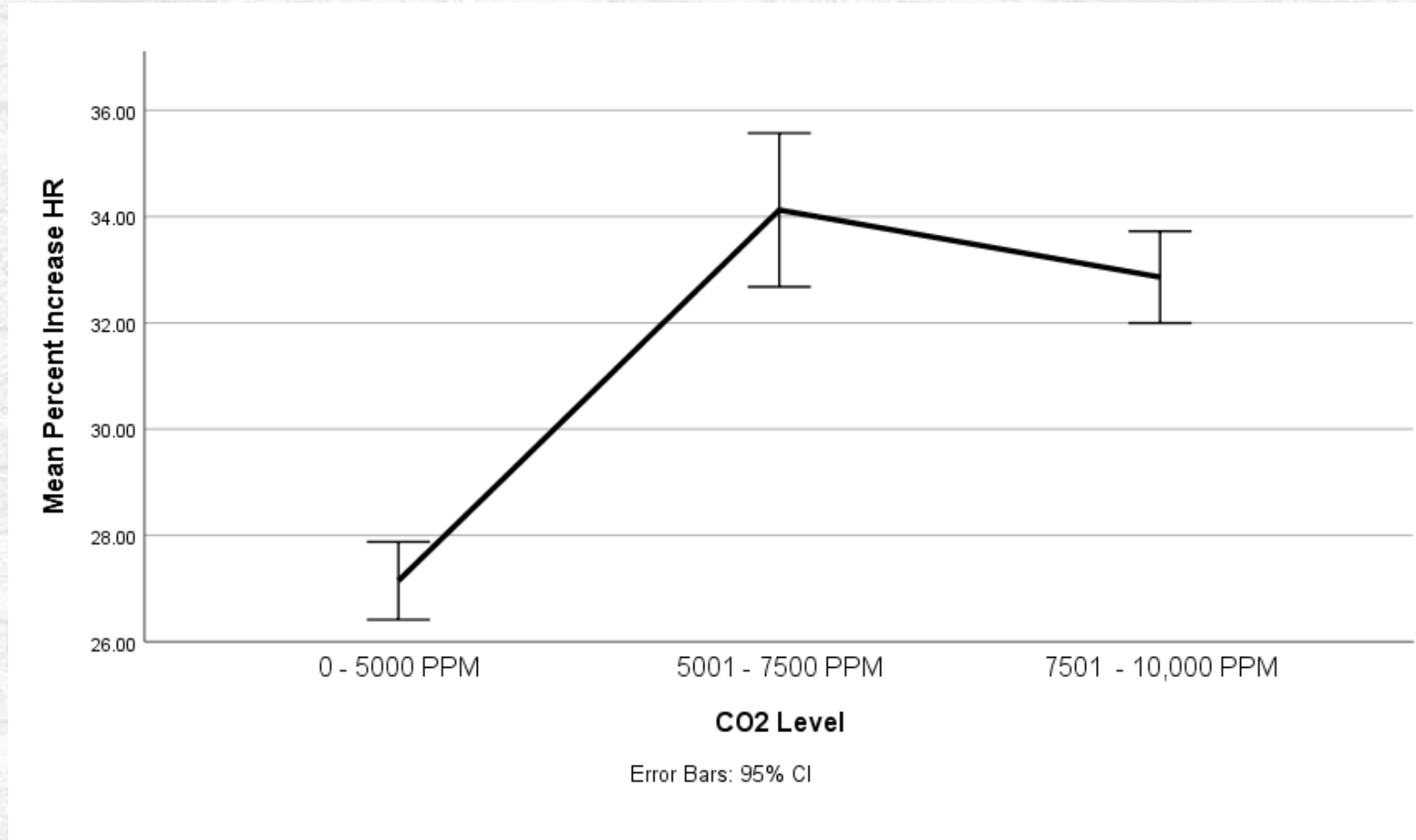
NASA TLX By Job Task



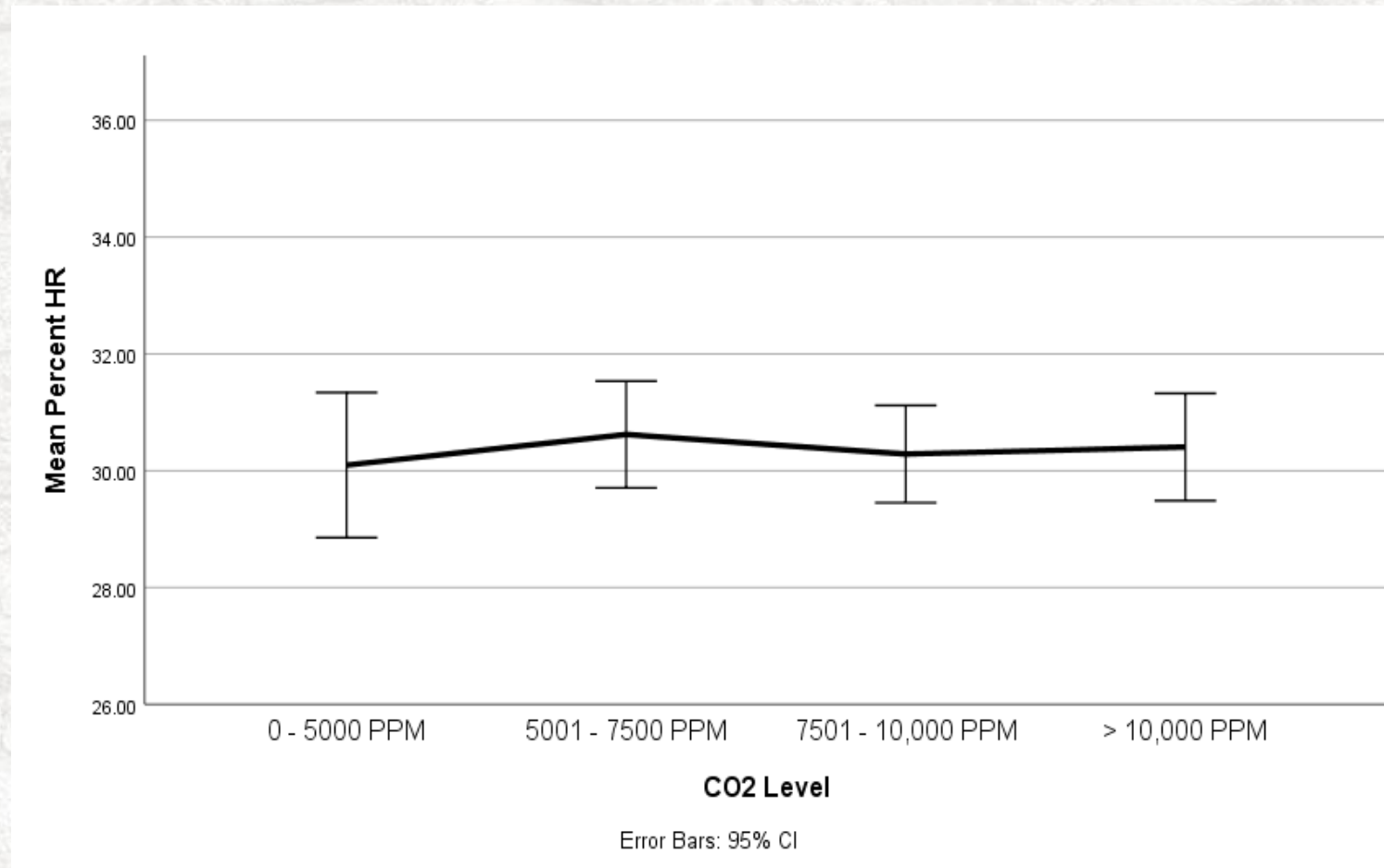
Percent Heartrate Increase By Job Task



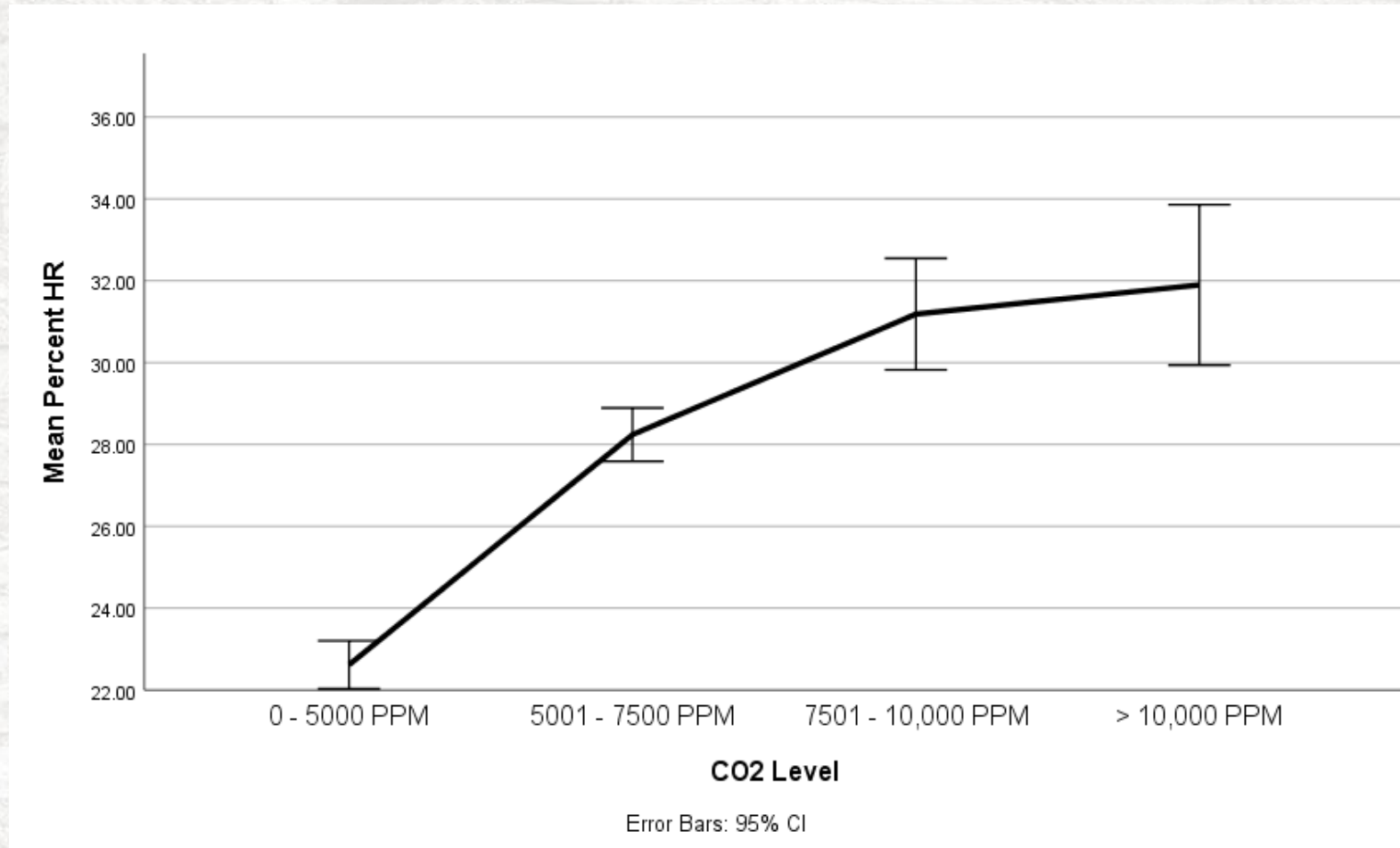
Barrel Filling Mean Percent Heart Rate increase By CO2 Concentration



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

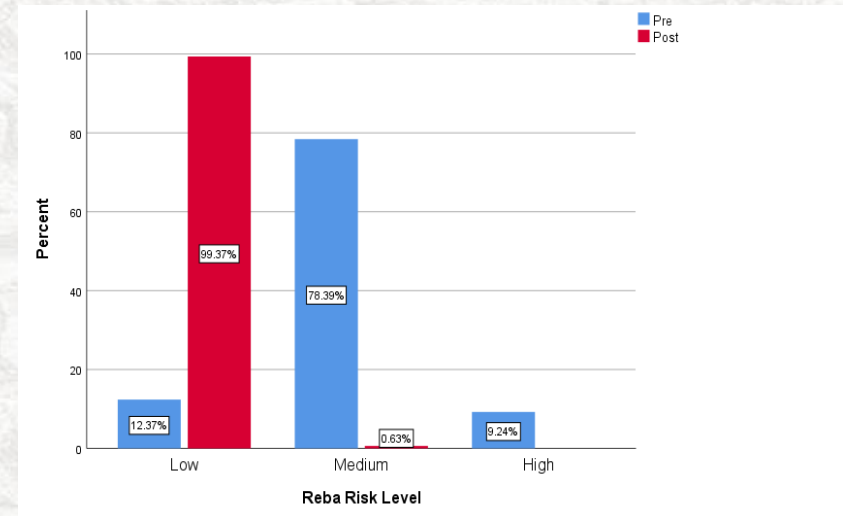
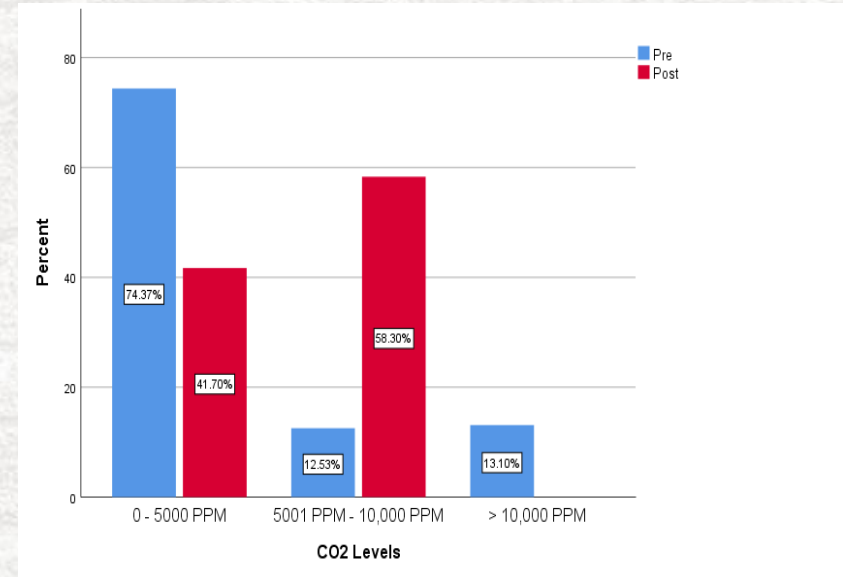


Canning Line
Dilution Ventilation



Cellar Extraction
Ventilation

Barrel Filling Control Evaluation

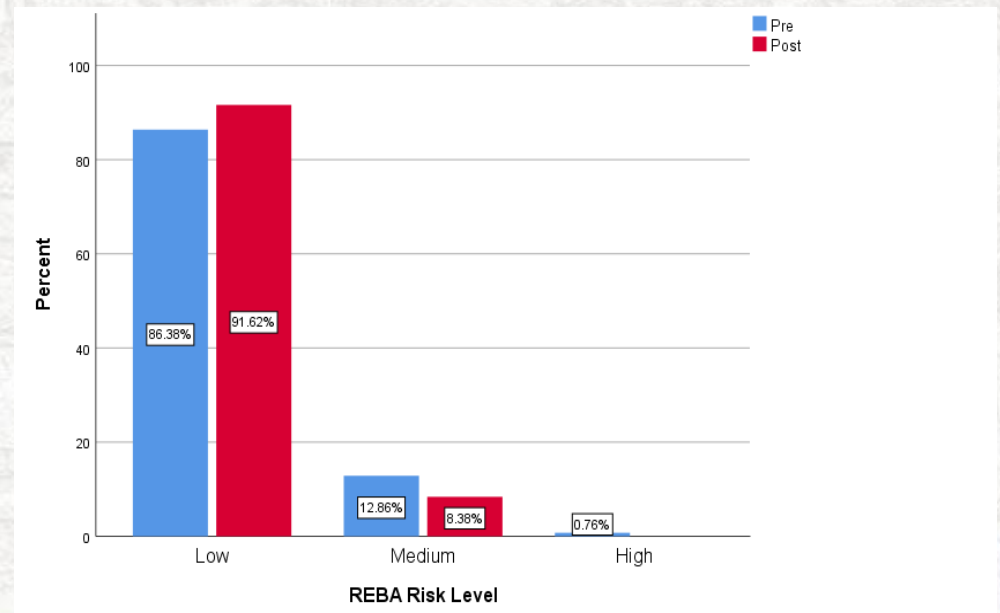
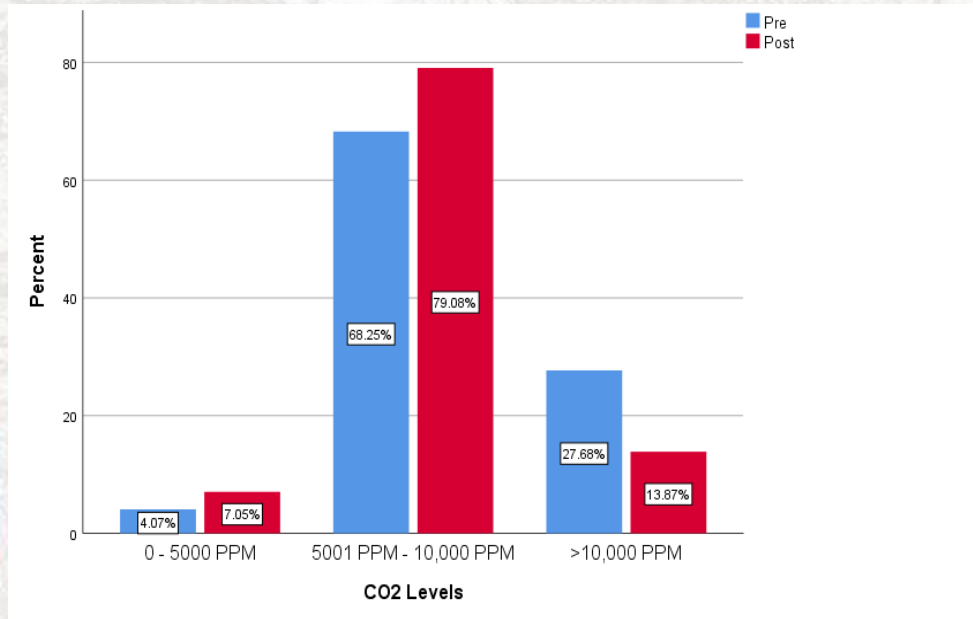


Barrel Filling Control Evaluation



	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

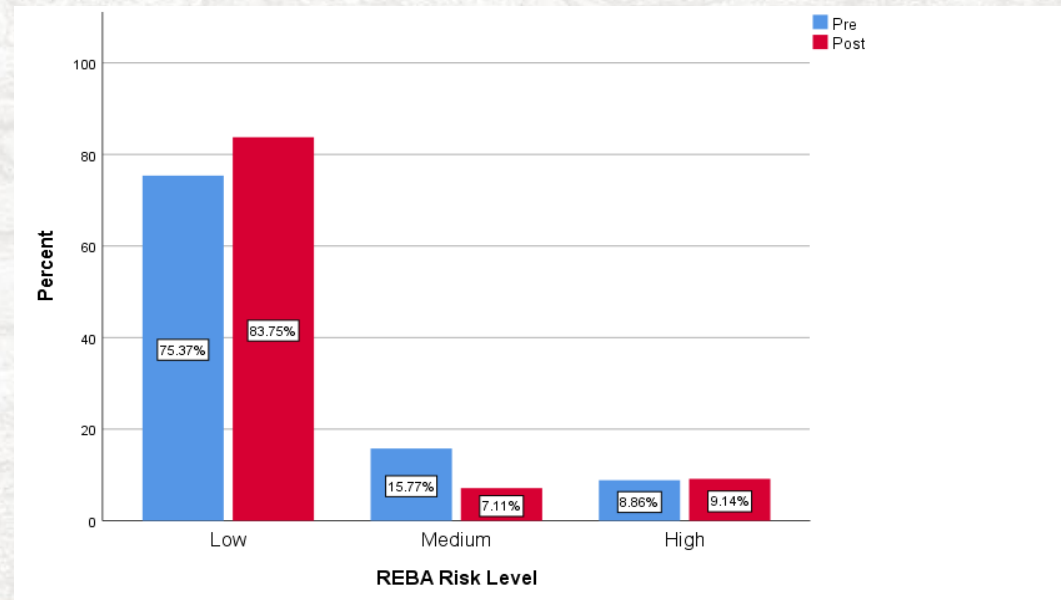
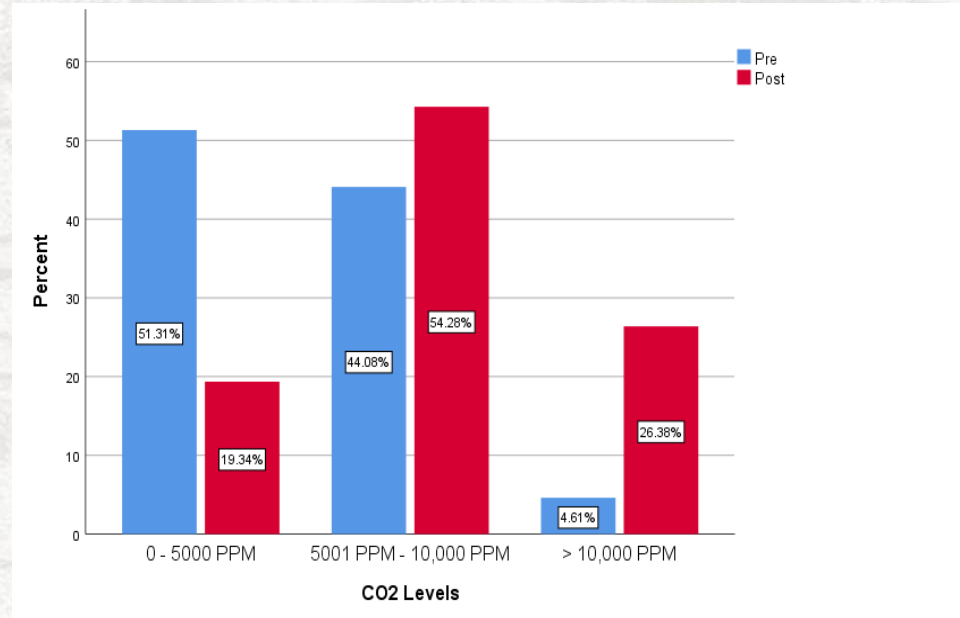


Canning Filler Control Evaluation



	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 – CO₂ Brewery Levels



Conclusions

- Levels of CO₂ 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 CO₂ exposures.
- The production cycle on a daily basis affects CO₂ levels in small and Mid-Sized Breweries
- The more areas are separated in a brewery the greater the CO₂ exposures.
- CO₂ exposure levels are dependent on square footage, Fermentation capacity, and production levels.

Workload, Biomechanical Stressors, and CO₂ 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 CO₂ had the largest impact on heartrate in the cellar.
- Consistently high levels of CO₂ 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 CO₂ 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
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- Cody Green – Founders
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Questions

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