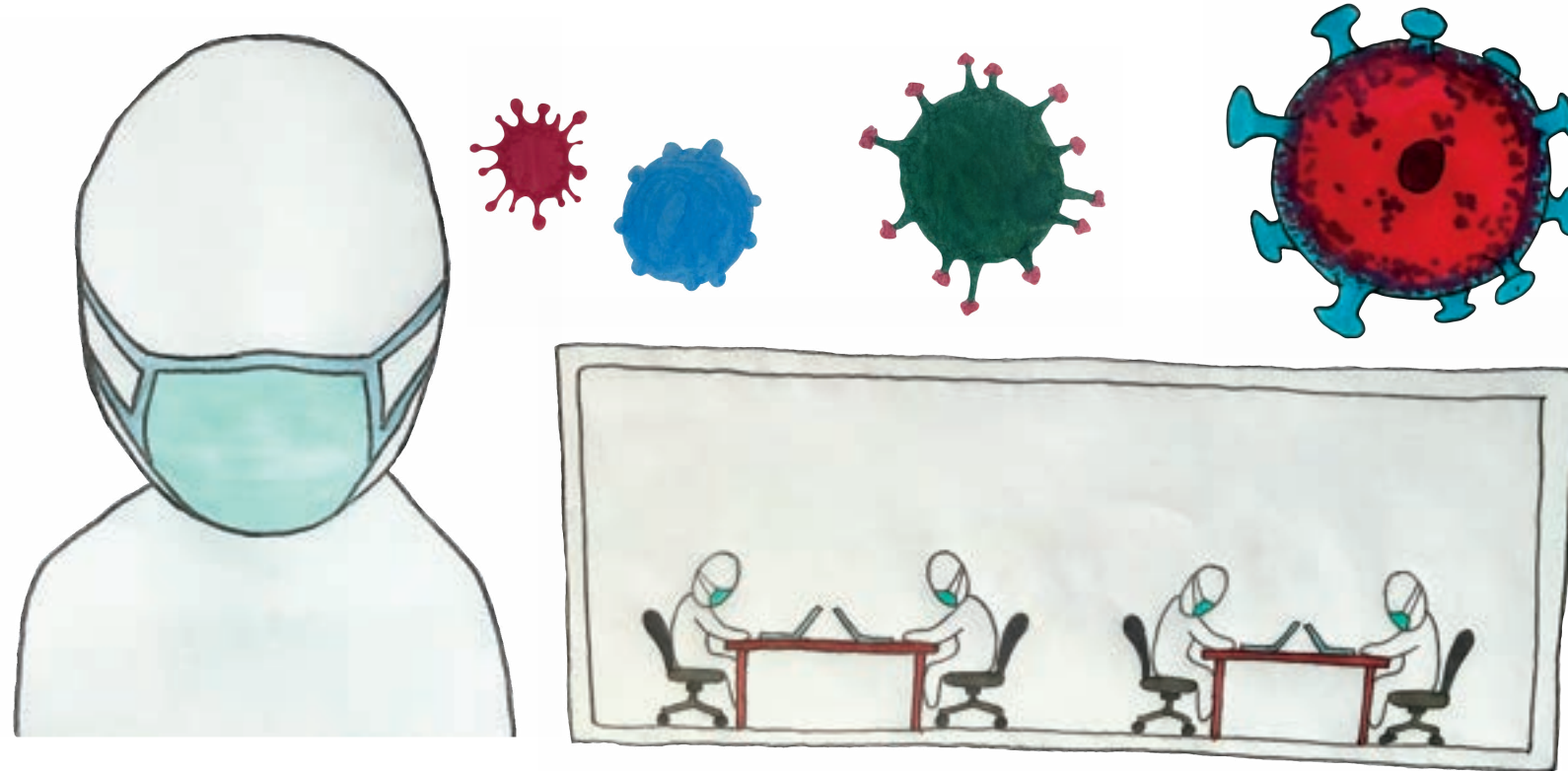## Aims
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Objectives
- Research the effects of plants on indoor environments.
- Investigate the benefits of Green Walls.
- Compare the performance of different plant species.
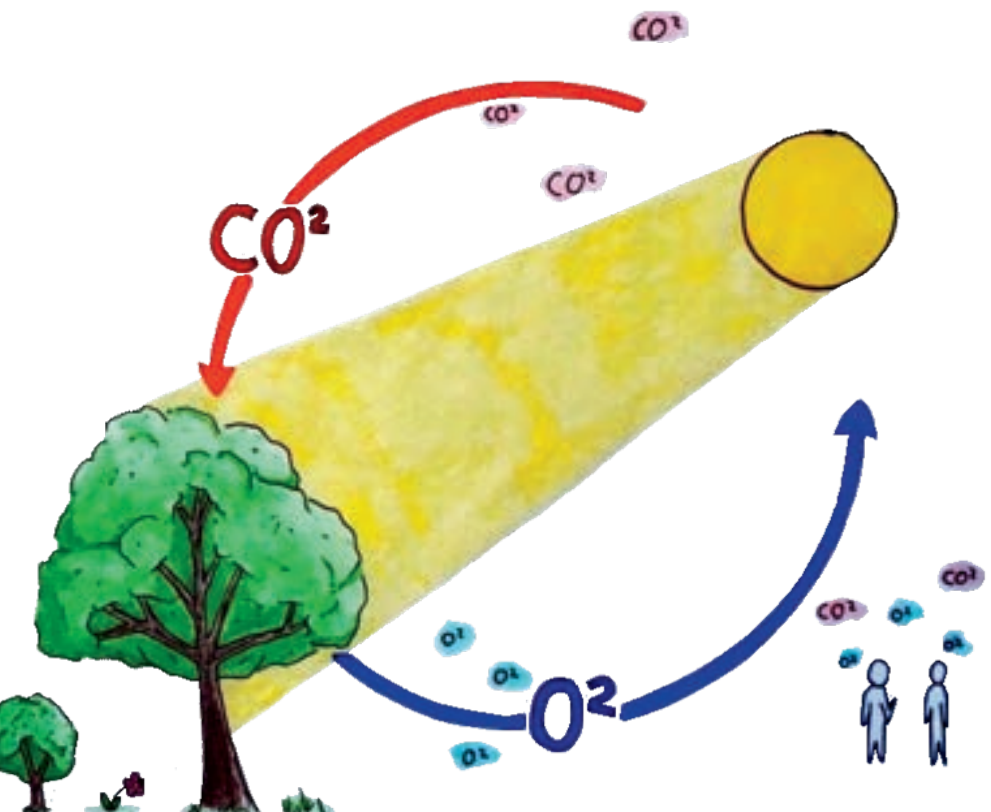- Examine the affect a Green Wall has on an indoor test environment.

Motivation

Methodology
- Construct a Green Wall prototype
- Monitor a test location for Carbon Dioxide, Temperature and Relative Humidity across 3 stages.
- Stage 1 - Without a Green Wall
- Stage 2 - With a Green Wall
- Stage 3 - Post Green Wall
- Compare and contrast reults

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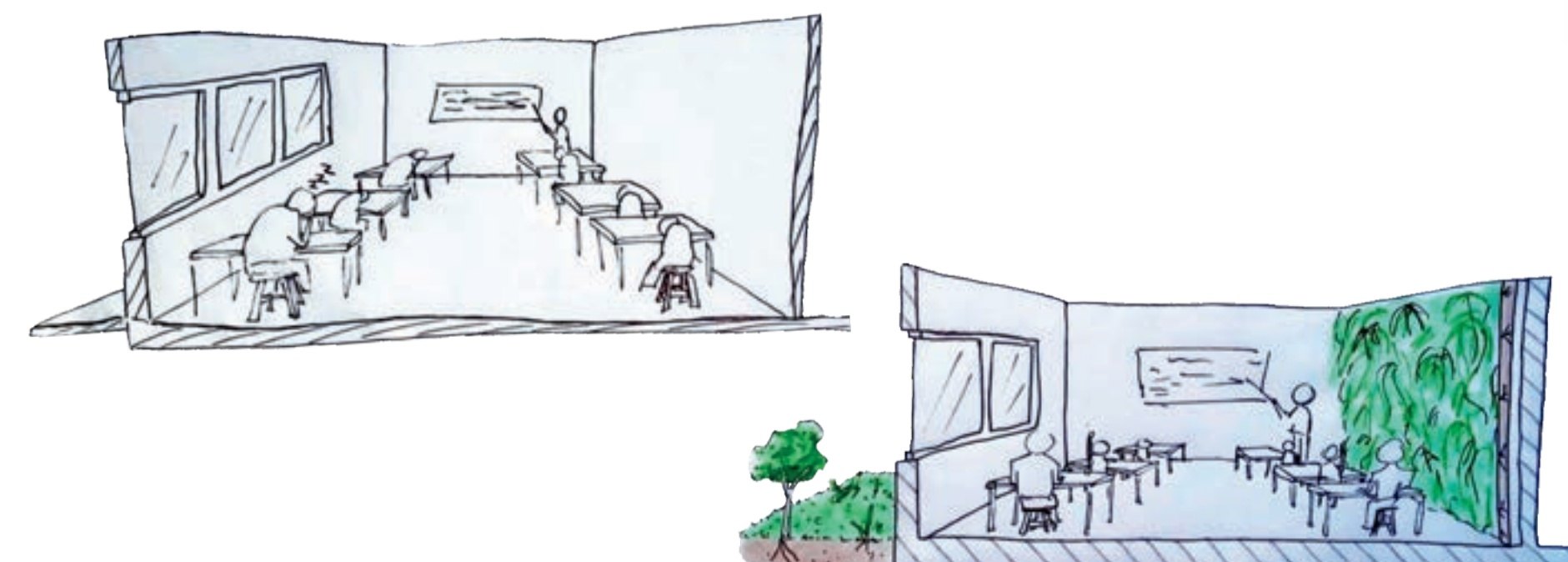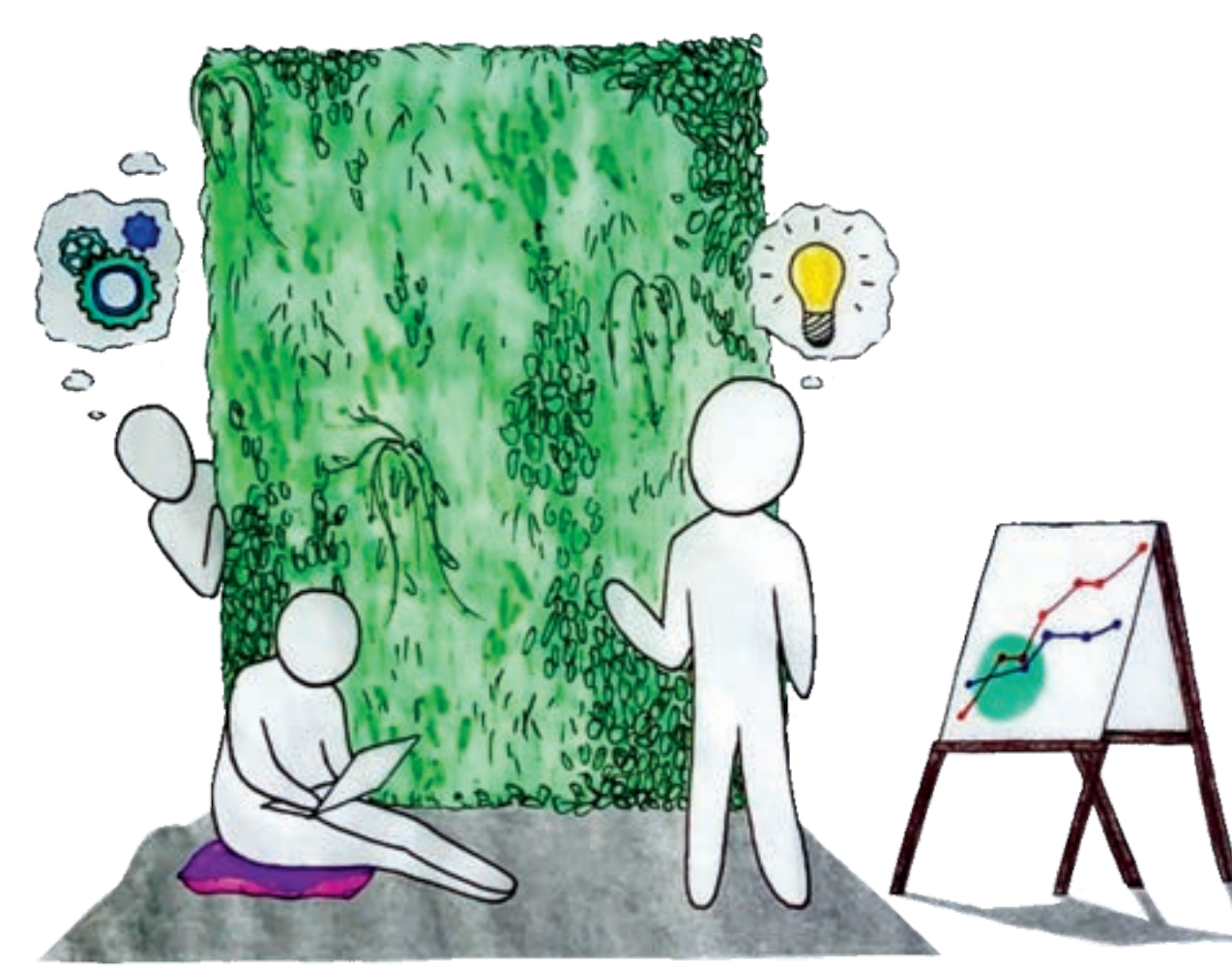
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Greenery has been connected to improved temperament, concentration and rigour in educational environments such as the classroom and university campus'.
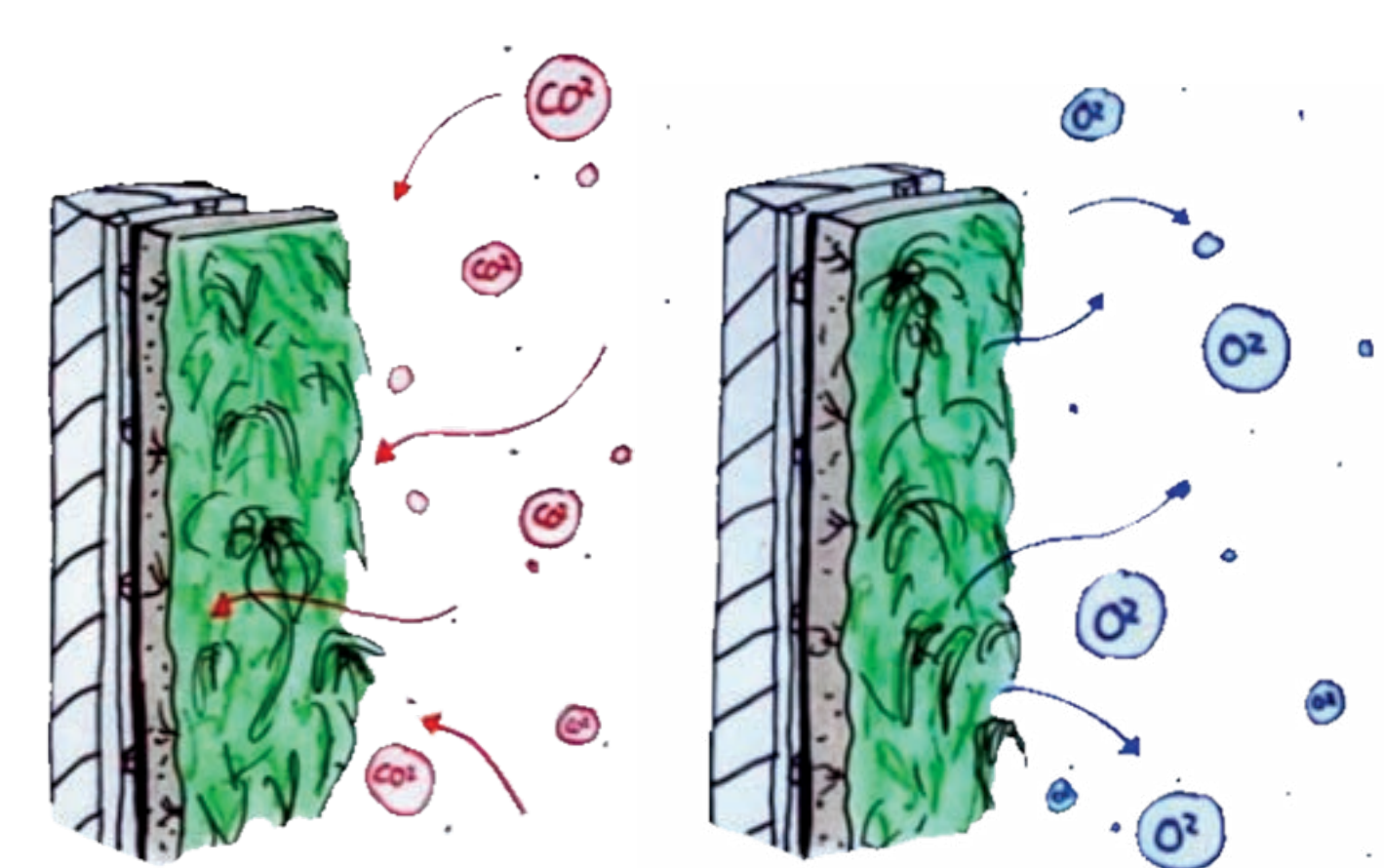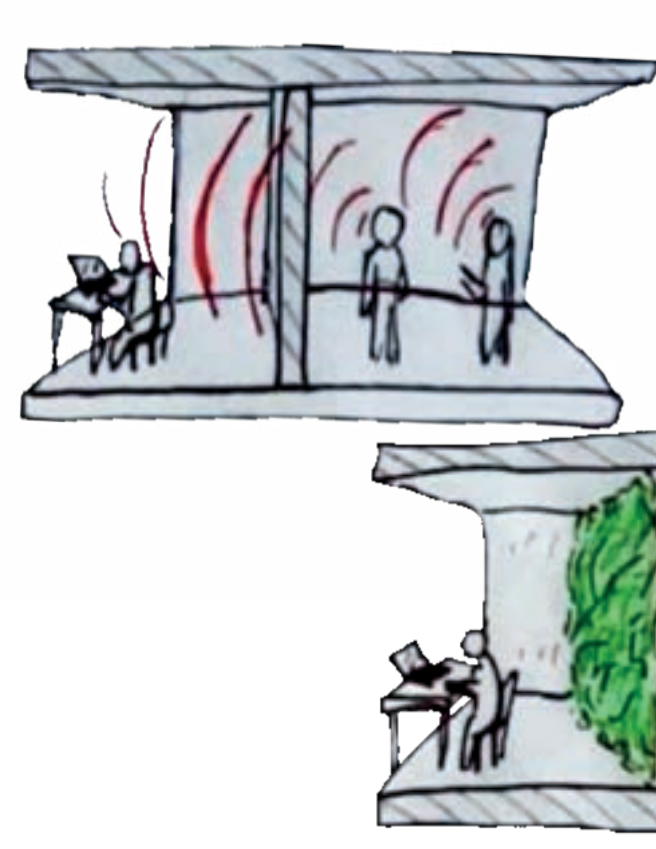
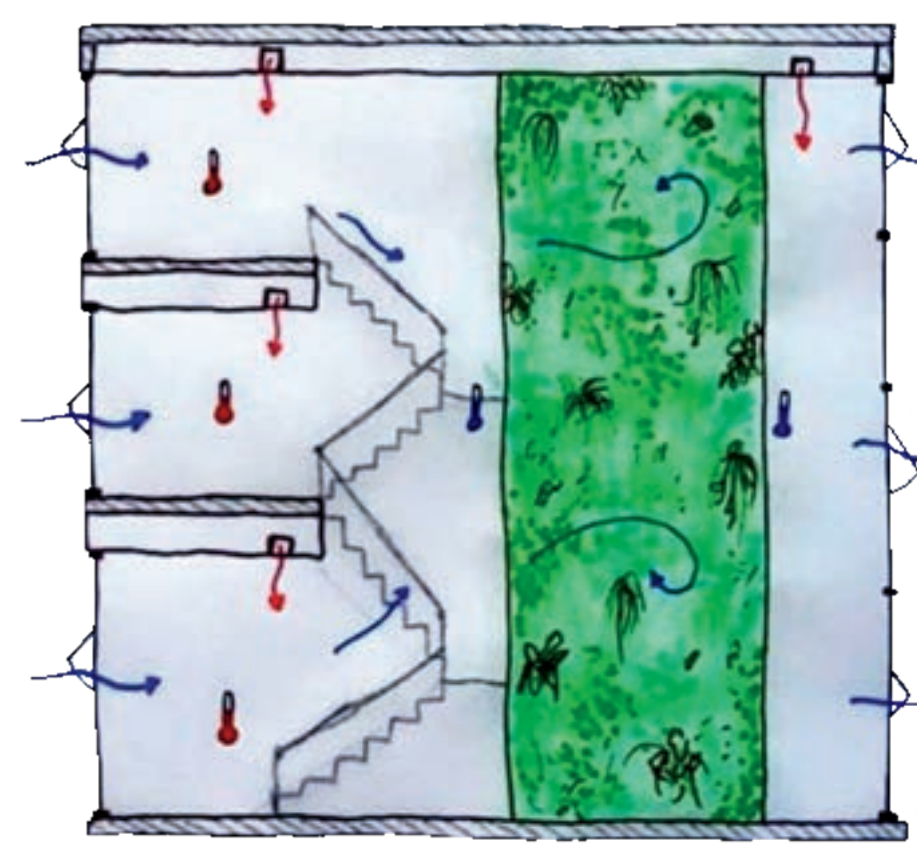Carbon Sequestration / Oxygen Output

Psychological Impact
- Improved Productivity
- Enhanced Creativity
- Enjoyable Atmosphere
- Increase Concentration
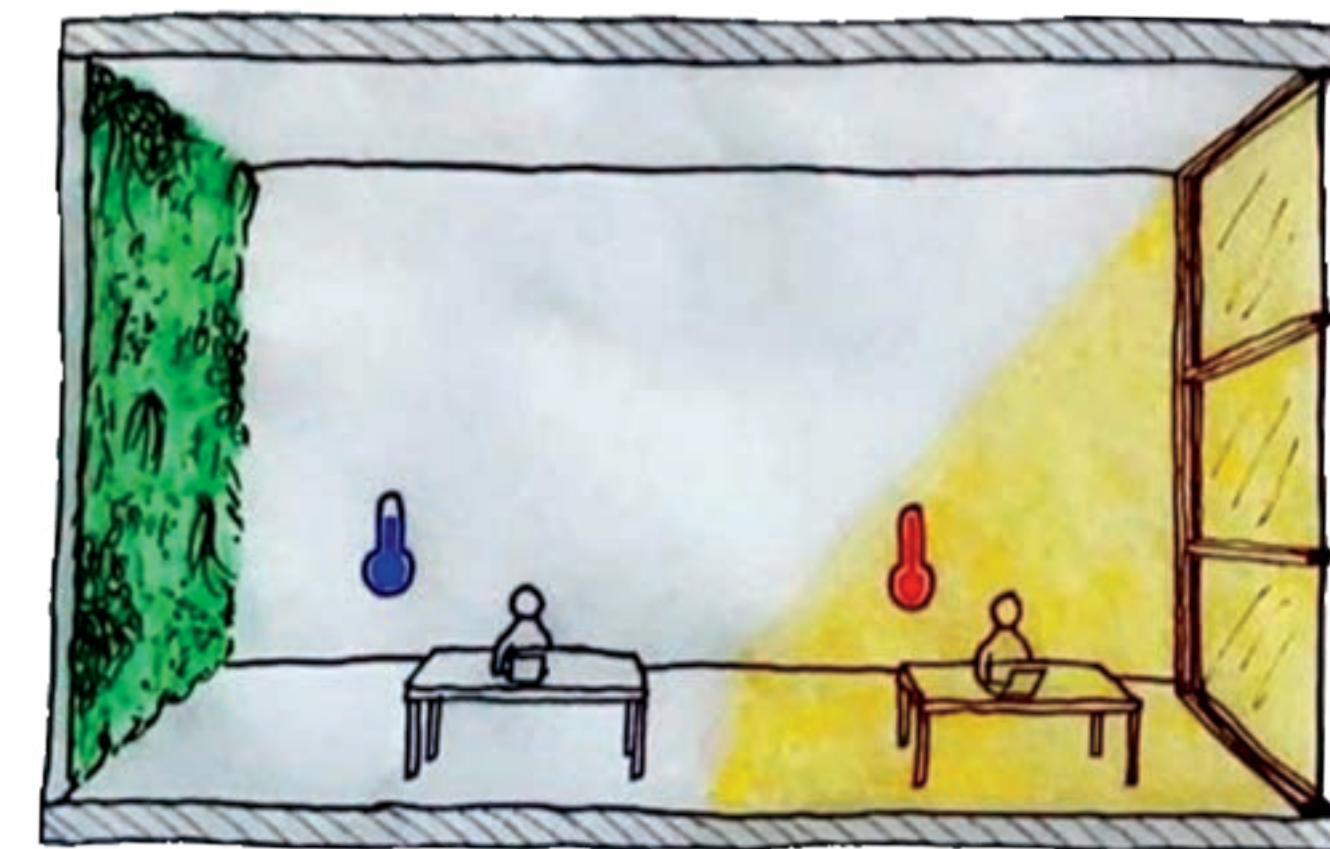- Decrease Stress
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Physiological Impact
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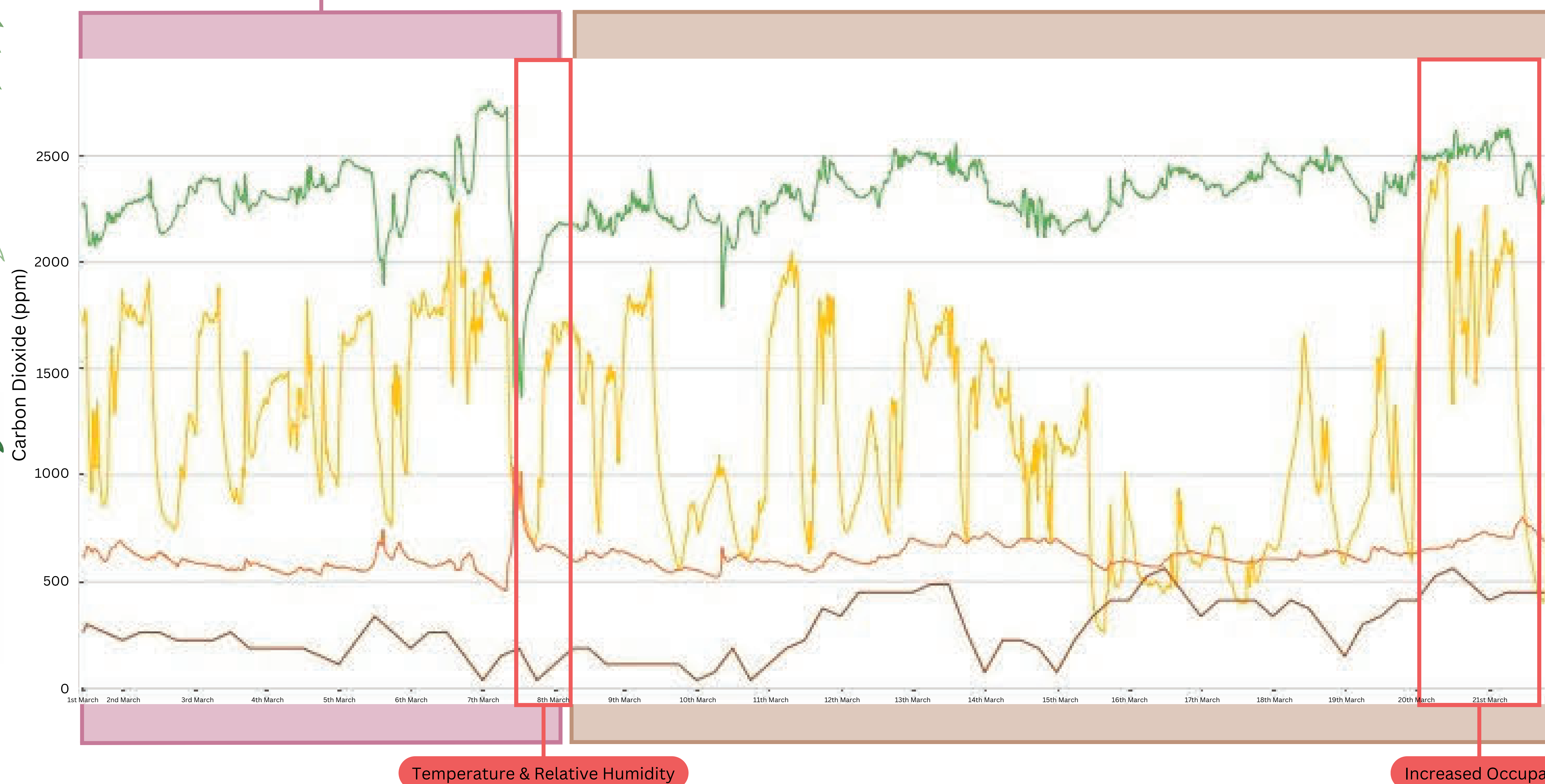- Reduce Migraines
- Mitigate VOC's

Sound Absorption

Humidity Control

Temperature Stabilisation

Phase 1

Carbon Dioxide (ppm)
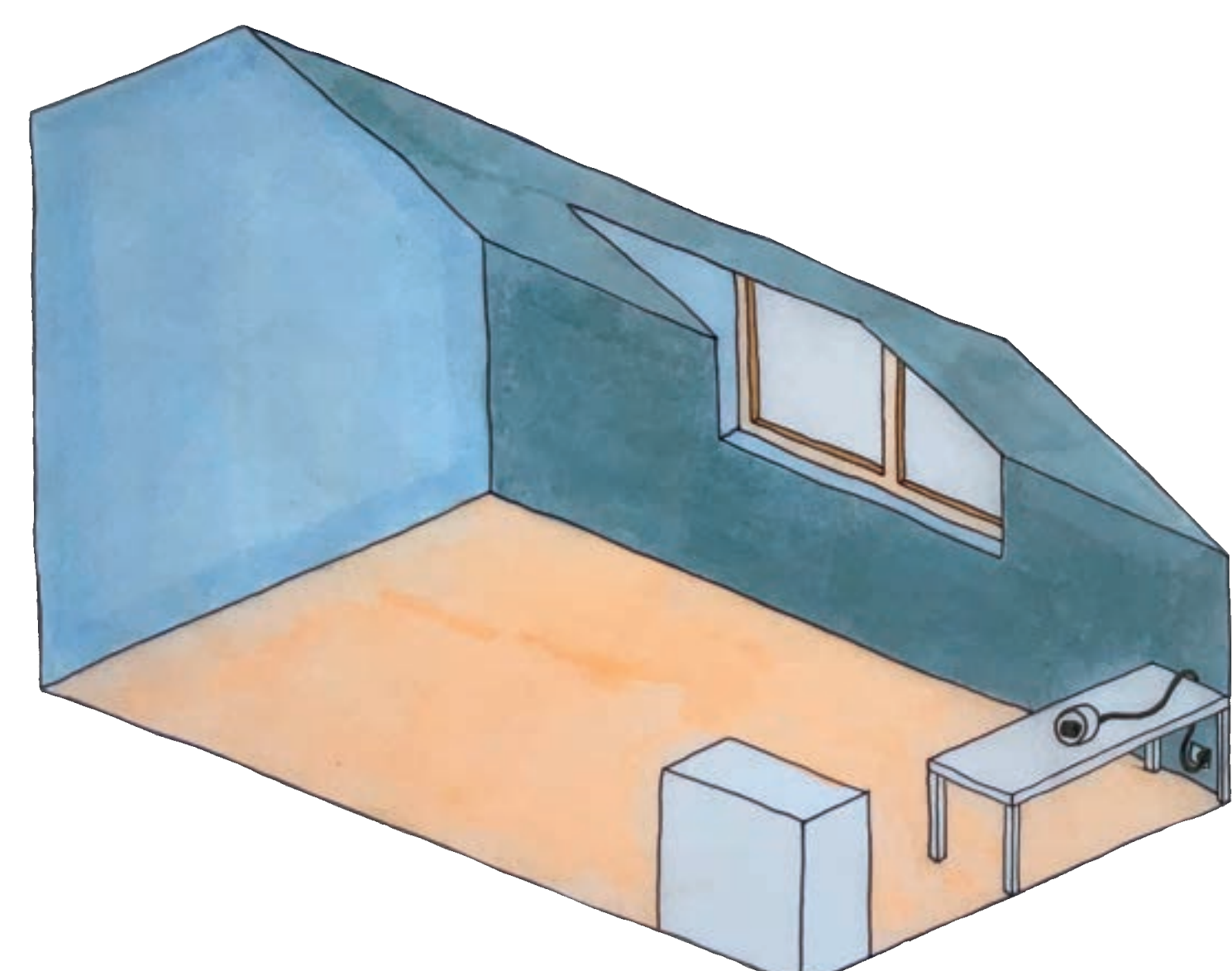
Temperature & Relative Humidity

Increased Occupa

Testing Phases
Monitoring the following elements to determine the quality of indoor air; Carbon Dioxide (CO2), Temperature (°C) and Relative Humidity (%).

Phase 1
Pre Room Monitoring
Monitoring the indoor air quality of the test location prior to the installation of the Green Wall prototype. The purpose of this phase is to gain an understanding of the existing air quality in order to create a comparator when the Green Wall prototype is introduced to the location.

Time Period;
1 Week - March 1st 2023 until March 8th 2023

Phase 2
Green Wall Monitoring
Monitoring the indoor air quality of the test location upon the installation of the Green Wall prototype. The purpose of this phase is to assess if the presence of a Green Wall prototype in the test location does or does not have any impact on the air quality.

Time Period;
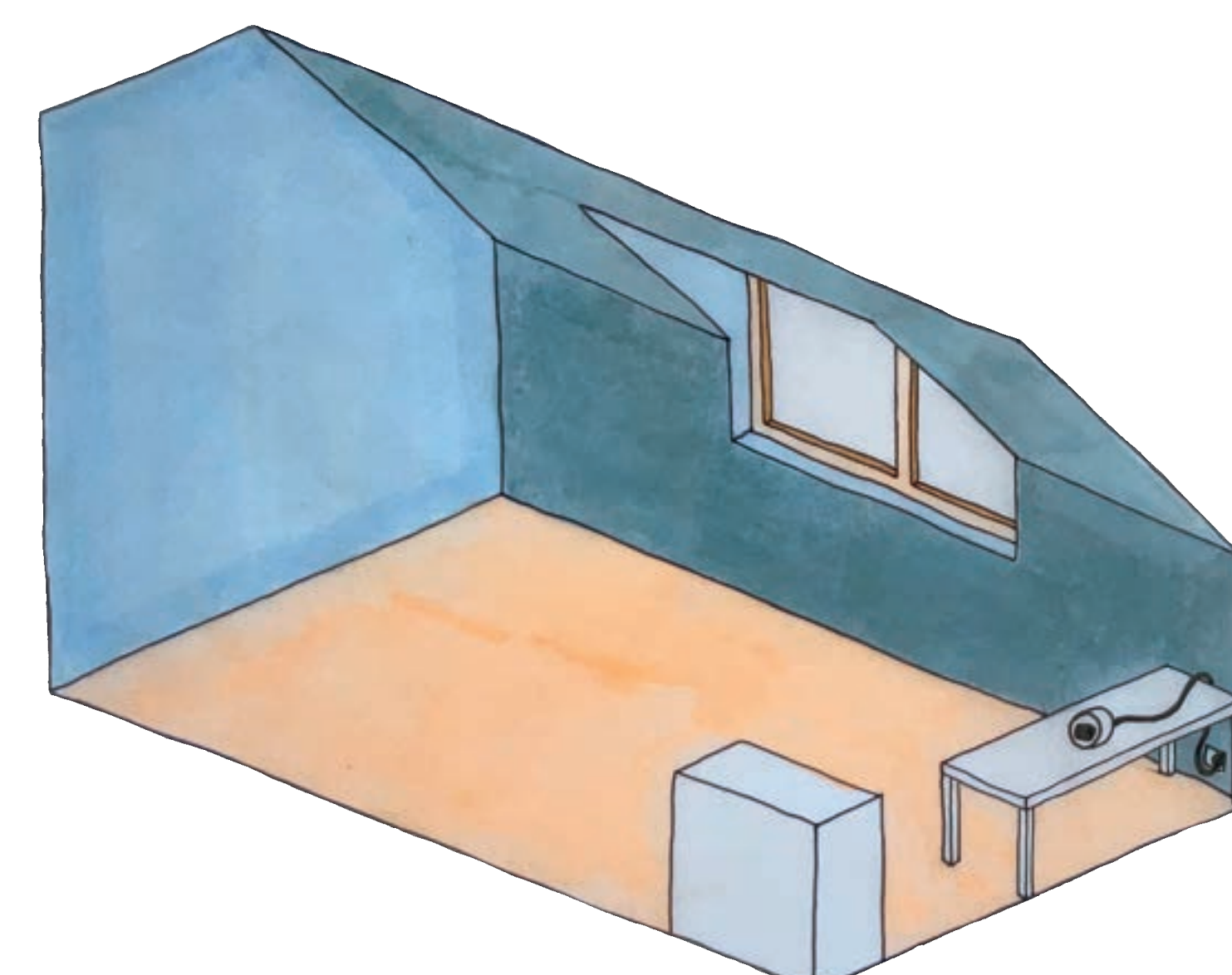7 Weeks - March 8th 2023 until 26th April 2023

Phase 3
Post Room Monitoring
Monitoring the indoor air quality of the test location upon the removal of the Green Wall prototype. The purpose of this phase is to determine if any changes (if any occurred) during Phase 2 were as a result of the Green Wall prototype and not unseen factors.
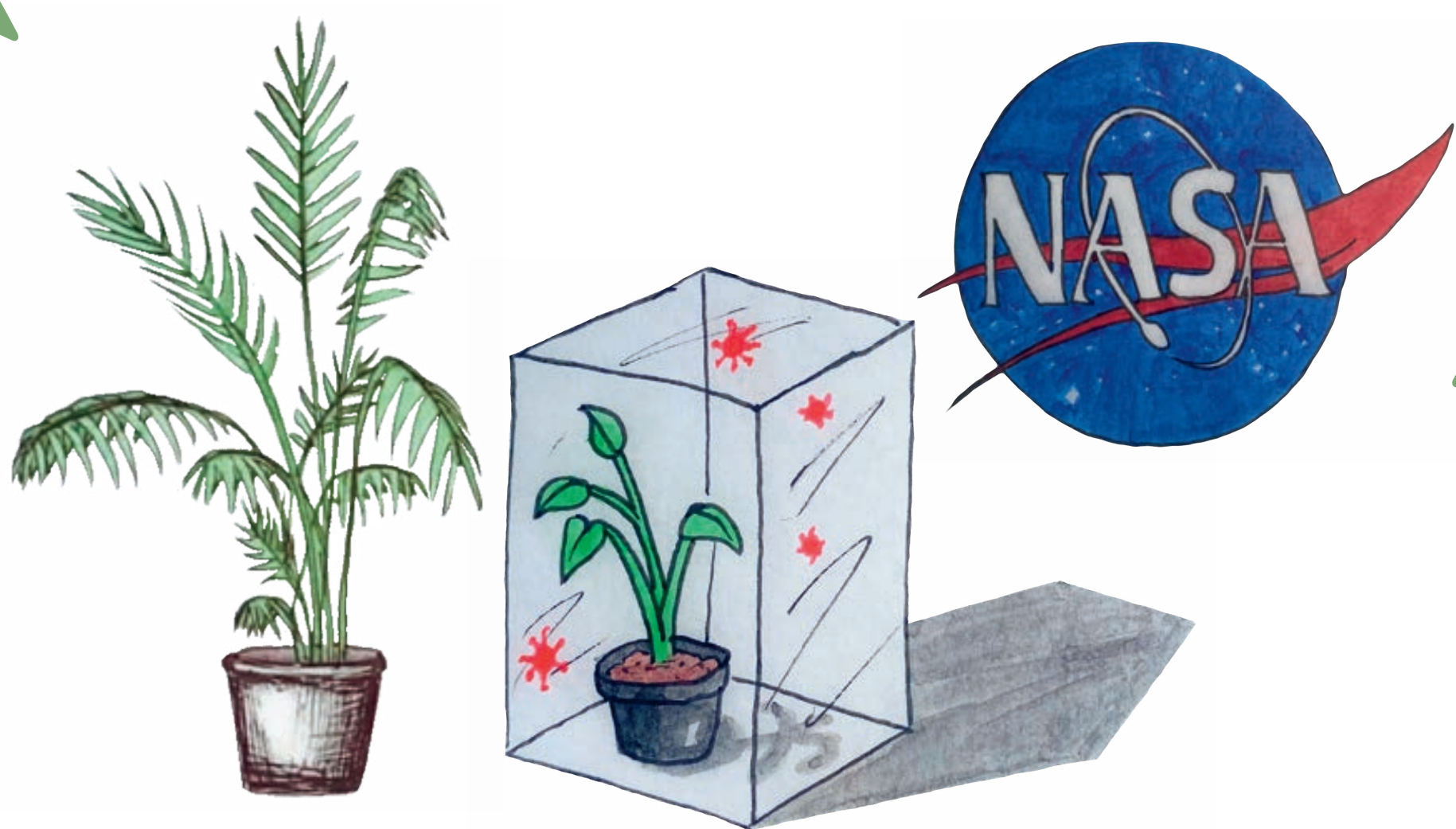
Time Period;
1 Week - April 26th 2023 May 3rd 2023

NASA

In 1989 NASA tested various species of indoor plants for their ability to aid in air purification. The plants were tested in sealed Plexiglas containers over a period of 24 hours to see if they could remove certain VOC's from within. The study was successful and the paper concluded that the presence of indoor planting can help alleviate Sick Building Syndrome.
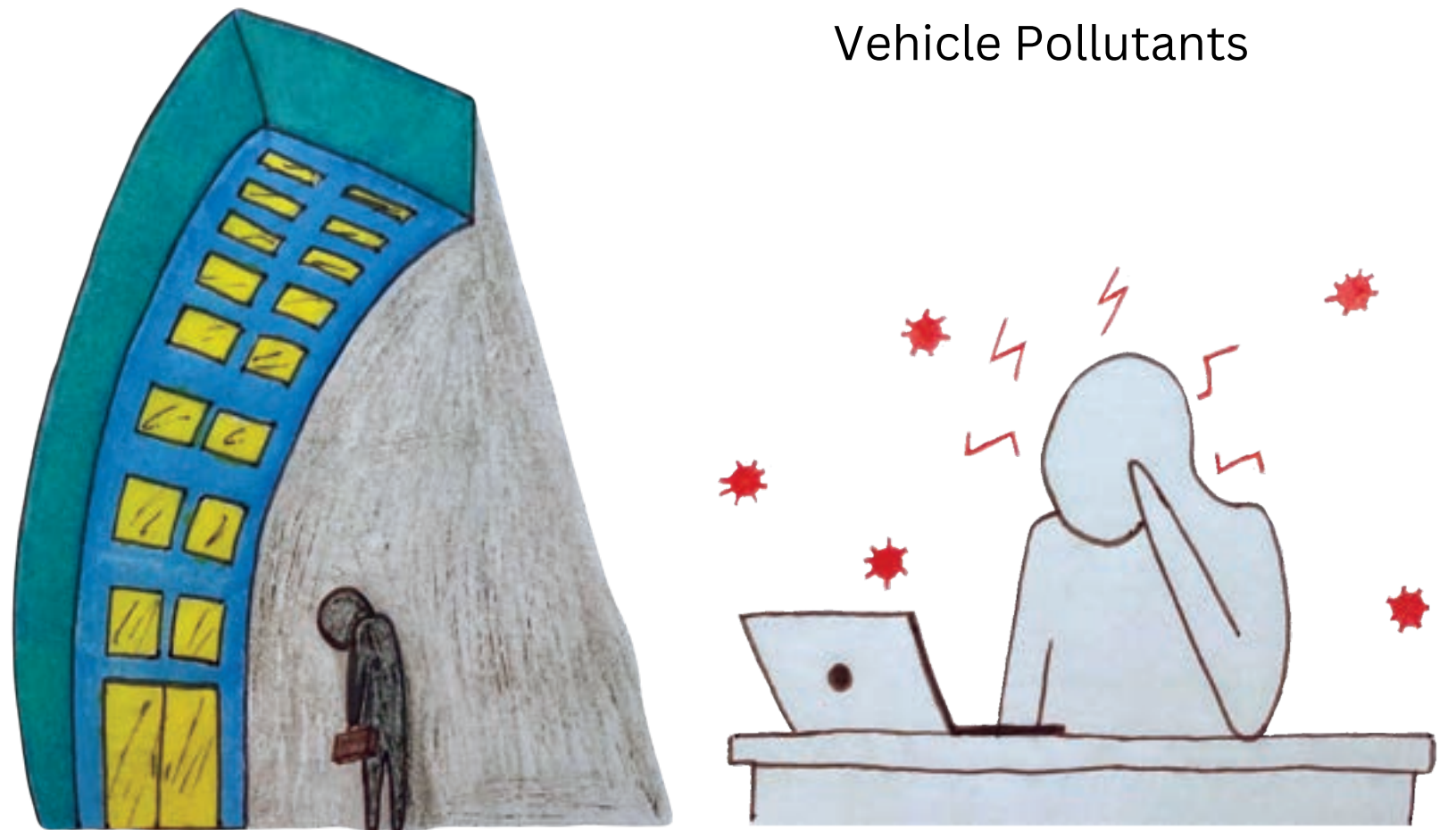
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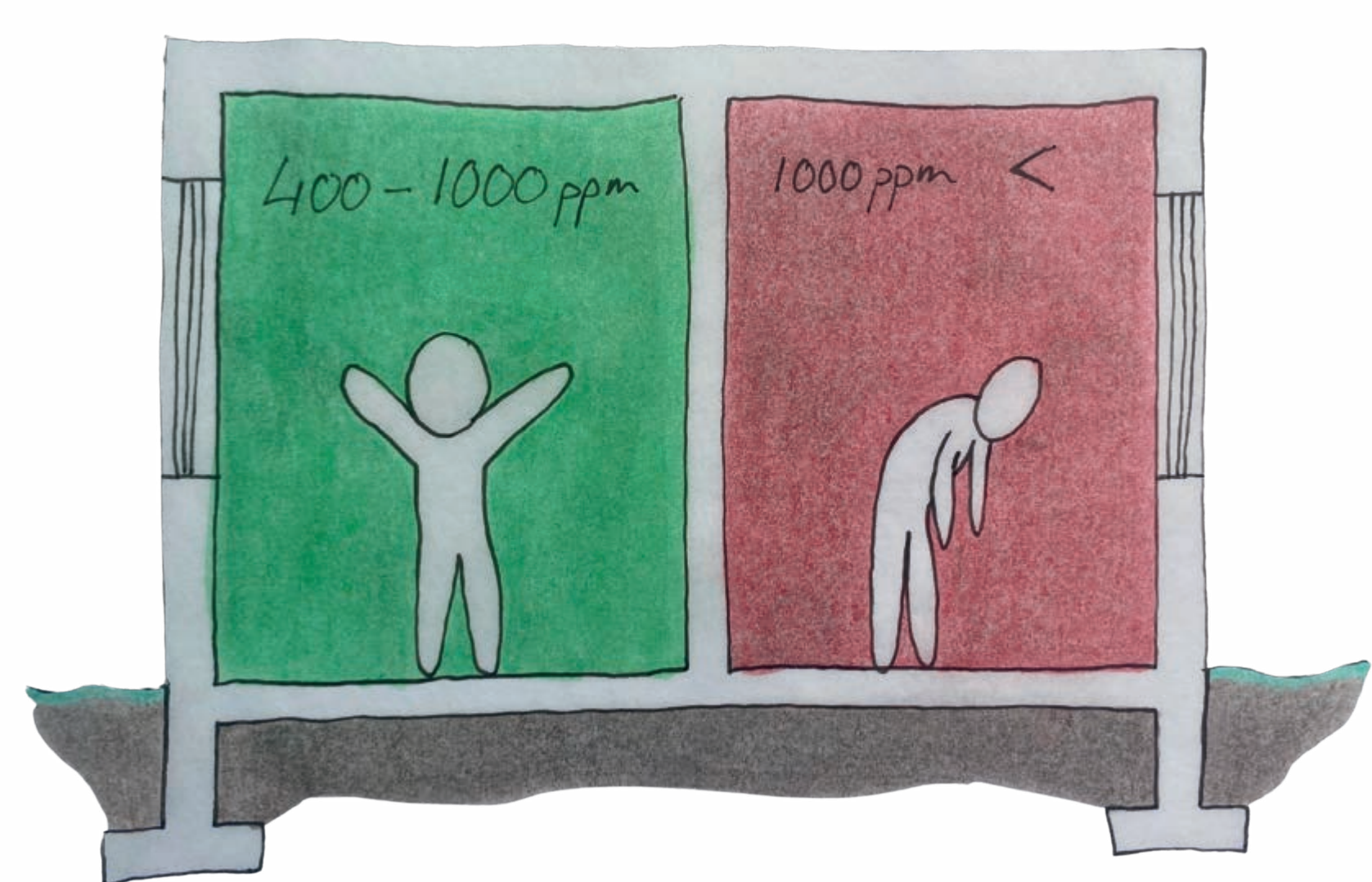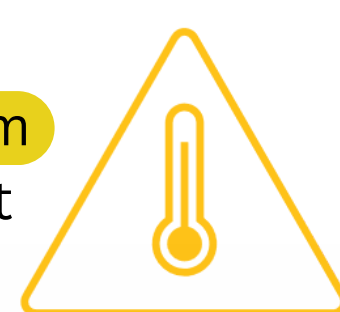- Dry Eyes
- Sore Throat
- Tiredness

Common causes include;
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- Dust
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- VOC's
- Outdoor Contaminants - Vehicle Pollutants
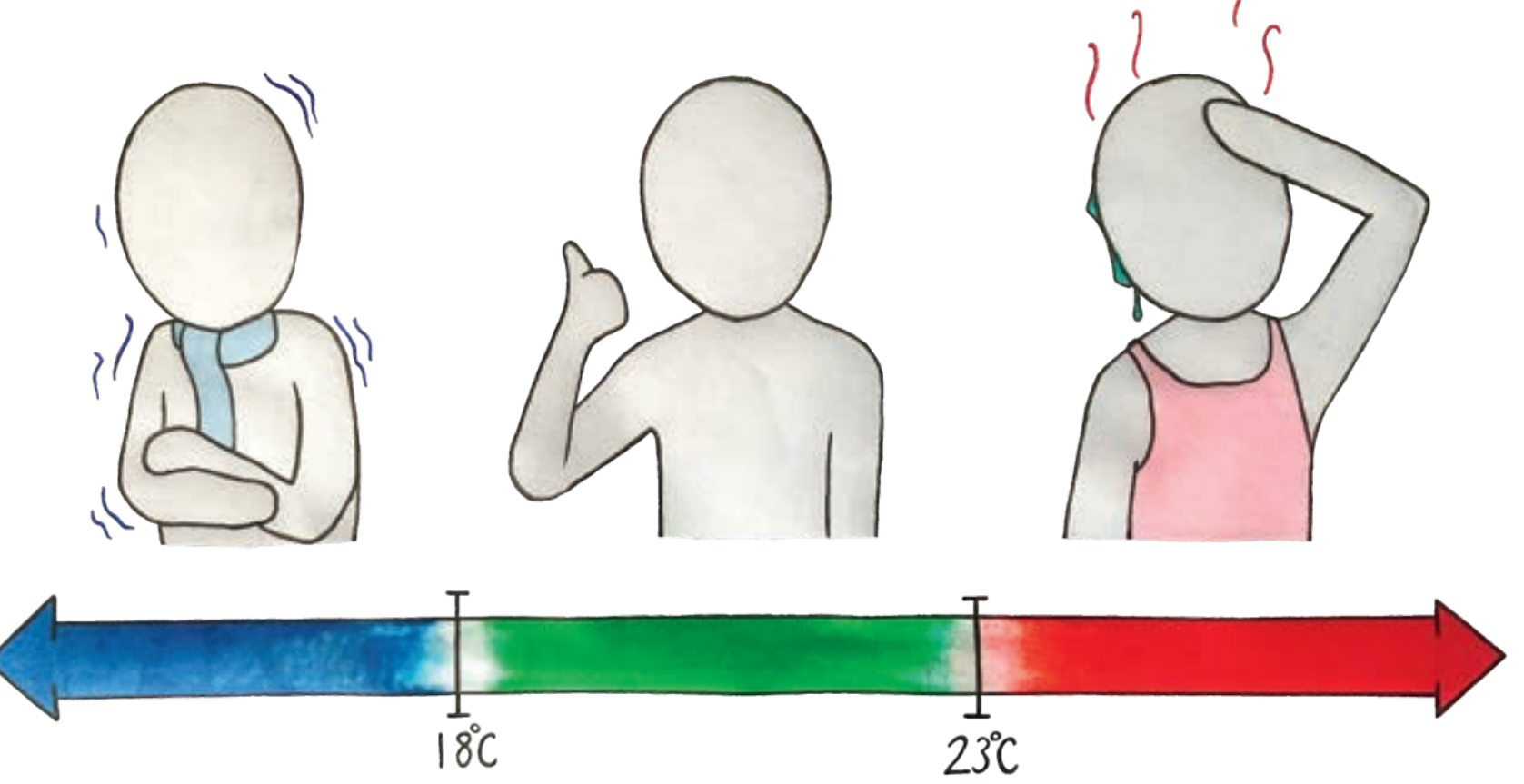
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According to the HSE, an indoor room temperature should be around 20 Degrees Celsius. A range in temperature of about 18 to 23°C is considered a comfortable range.

Minimum temperatures by Health and Safety Authority;

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Relative Humidity (RH) is the measurement of water vapour in the air relative to it's temperature.

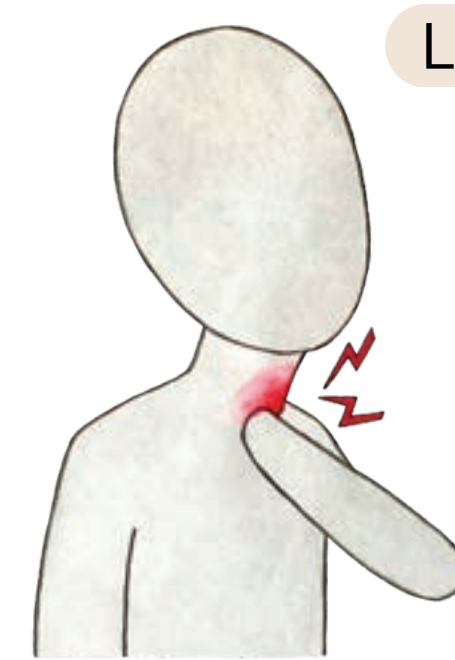Ideal Range : 40 - 60%

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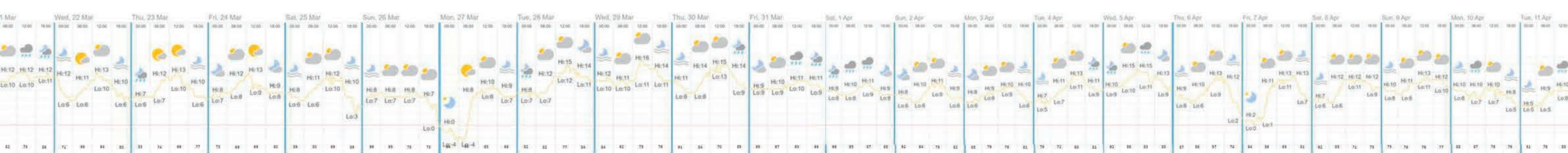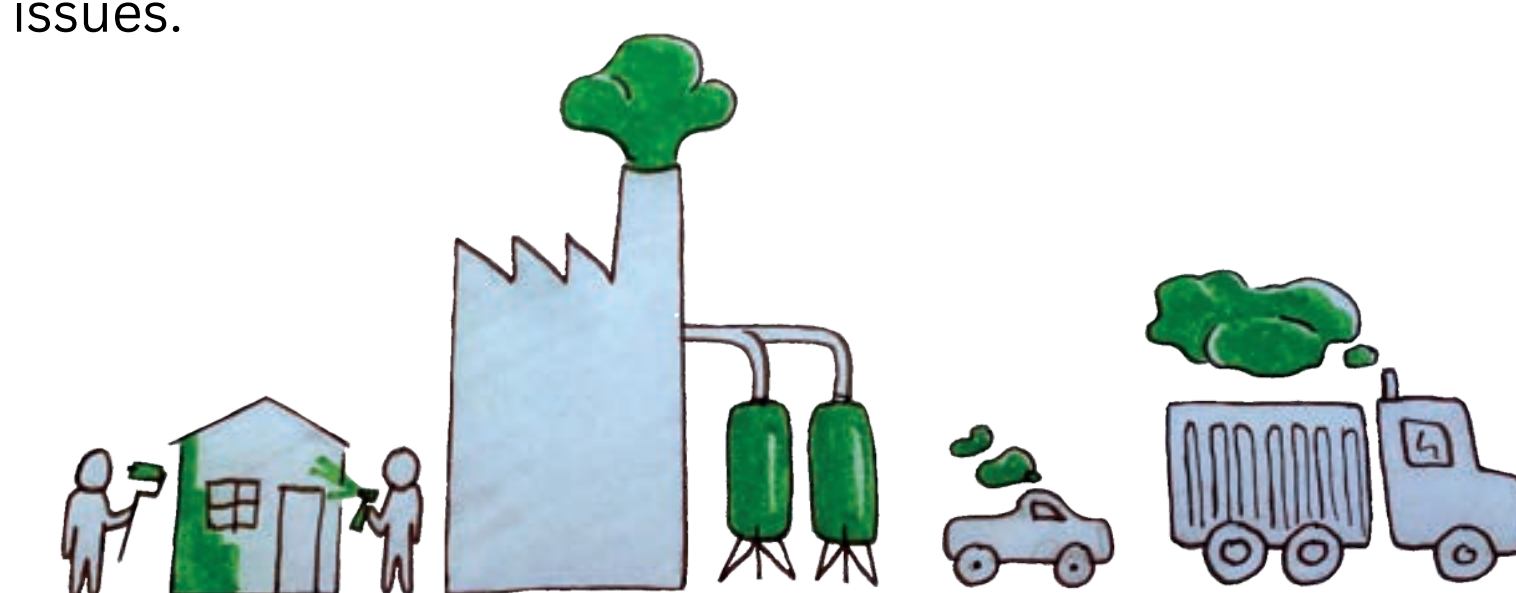- Concentration of VOC's.

Low Relative Humidity;
- Health implications - (Sore throat, dry skin / lips / eyes)
- Respiratory illnesses
- Spread of Virous'
- Deterioration of materials and finishes - (Wallpaper peeling / shrinkage & warpage of floorboards.)

Volatile Organic Compounds - VOCs

Volatile organic compounds, or VOCs are chemicals that are commonly emitted in gaseous forms from solids and liquids. VOCs are common in household items and materials, contributing to them being 10 times higher in indoor environments compared to outdoor.

VOCs are present in manmade products and materials, such as: particleboard, ceiling tile, carpet, glue, lacquer and varnish. They are connected to short and long term health issues.

Phase 2

CO2 (——), Temp (——), RH (——), External Temp (——)

22nd March 23rd March 24th March 25th March 26th March 27th March 28th March 29th March 30th March 31st March 1st April 2nd April 3rd April 4th April 5th April 6th April 7th April 8th April 9th April 10th April 11th April 12th April

ancy

Test Room

South Elevation

North Elevation

East Elevation

West Elevation

Floor Plan

3.75 X 2.85m   11m2 / 115 SF   22.6m3

Test Conditions

The Door and Window to the room were closed shut at all times, except when the door was used to move in and out of the room. The only source of ventilation is the 14cm X 10cm vent located in the ceiling.

These conditions were kept across all 3 testing phases.

Occupancy Routine

The test location functioned as a workspace during the day, with a rough schedule of 9-5 everyday. The room was then used for leisure and occupied for sleep every night.

These routines were kept across all 3 testing phases.

Furniture Plan

Bed

Desk

Side Table

Wardrobe

Dresser

Green Wall

Test Room 3D

Panel System
- Panels hold plants and growing medium.
- Usually secured with vertical and or horizontal supports to a primary wall.
- Reduce watering / maintenance
- Water Reservoirs / Irrigation Systems / Manual Watering

Felt System
- Lightweight felt sheet
- Secured to rigid backing board
- Felt pockets contain the planting and soil
- As plants grow and mature, their root systems grow into the felt system.
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- Benzene
- Xylene & Toluene
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Hedera Helix

Nephrolepis Boston Blue Bell

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Anthium

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The Green Eye CO2 Data Logger monitors and records Carbon Dioxide, Temperature and Relative Humidity levels.

The logger features a computer software to record gathered data. The data is displayed as a graphical chart. Charts show all three elements corresponding and can also show elements individually. Data can also be recorded as a text file.

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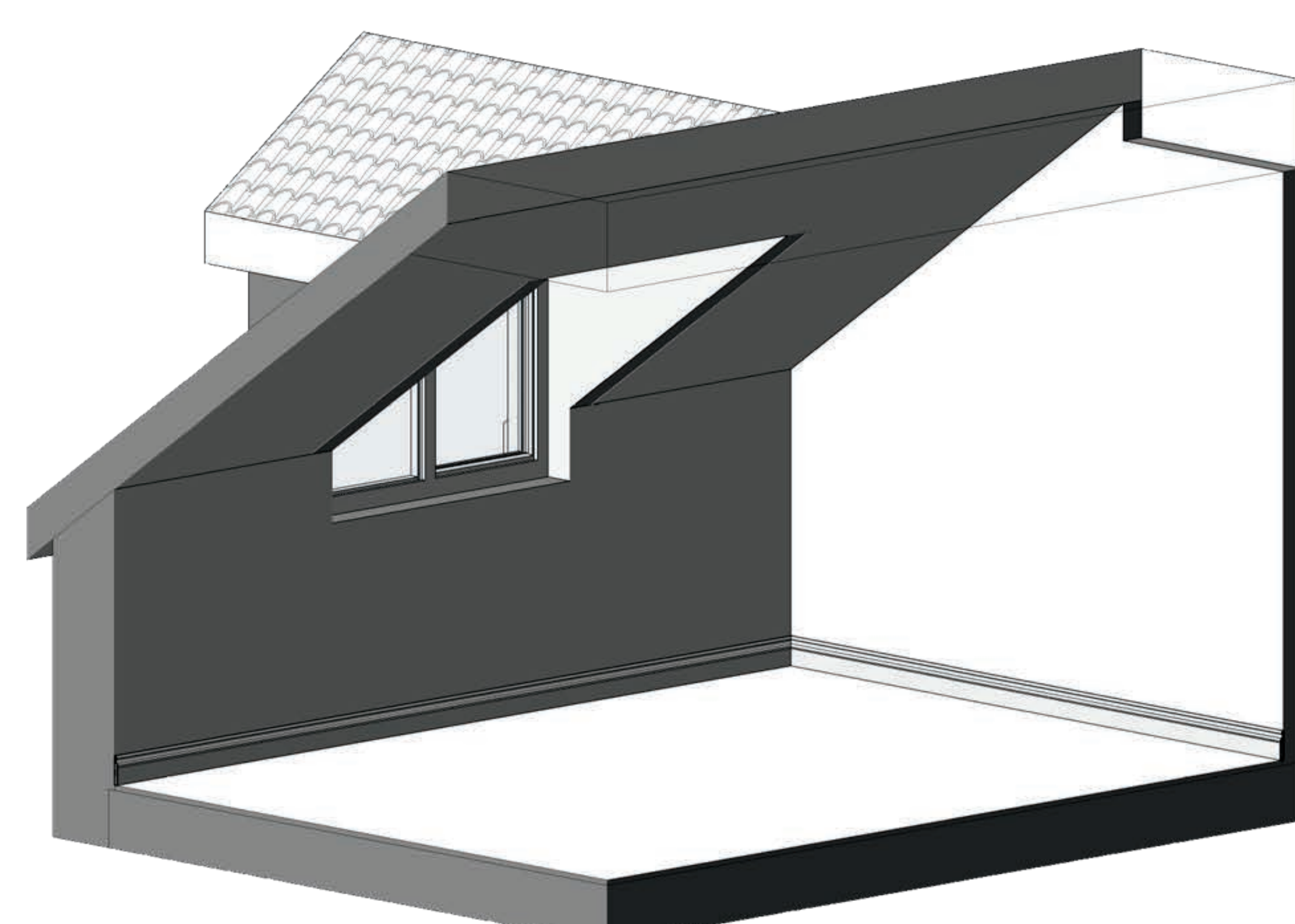
PlantBox - Growing Revolution
System consists of plant troughs with water resevoirs.. Troughs are vertically stackable and only requires secondary support to a fixed wall. Troughs are 600 X 200 X 150 mm. 4 plants per trough. Plants can be any size up to 12-13cm.

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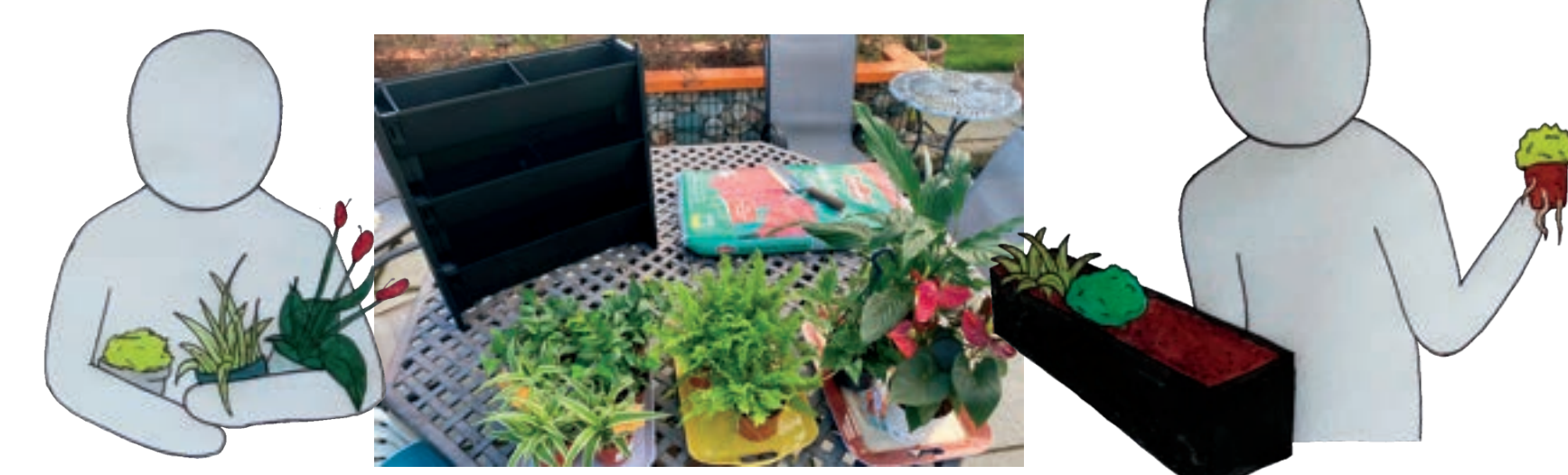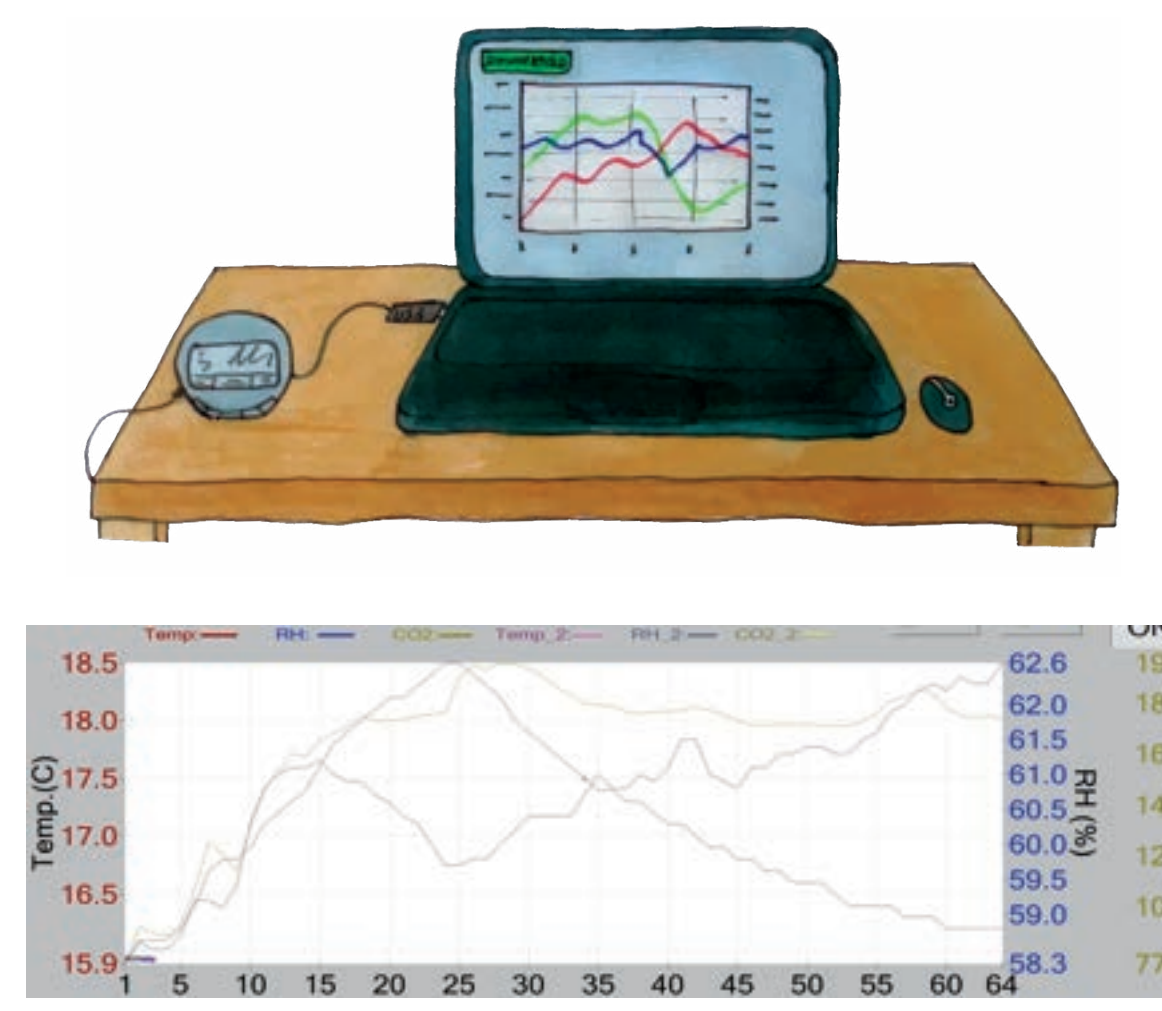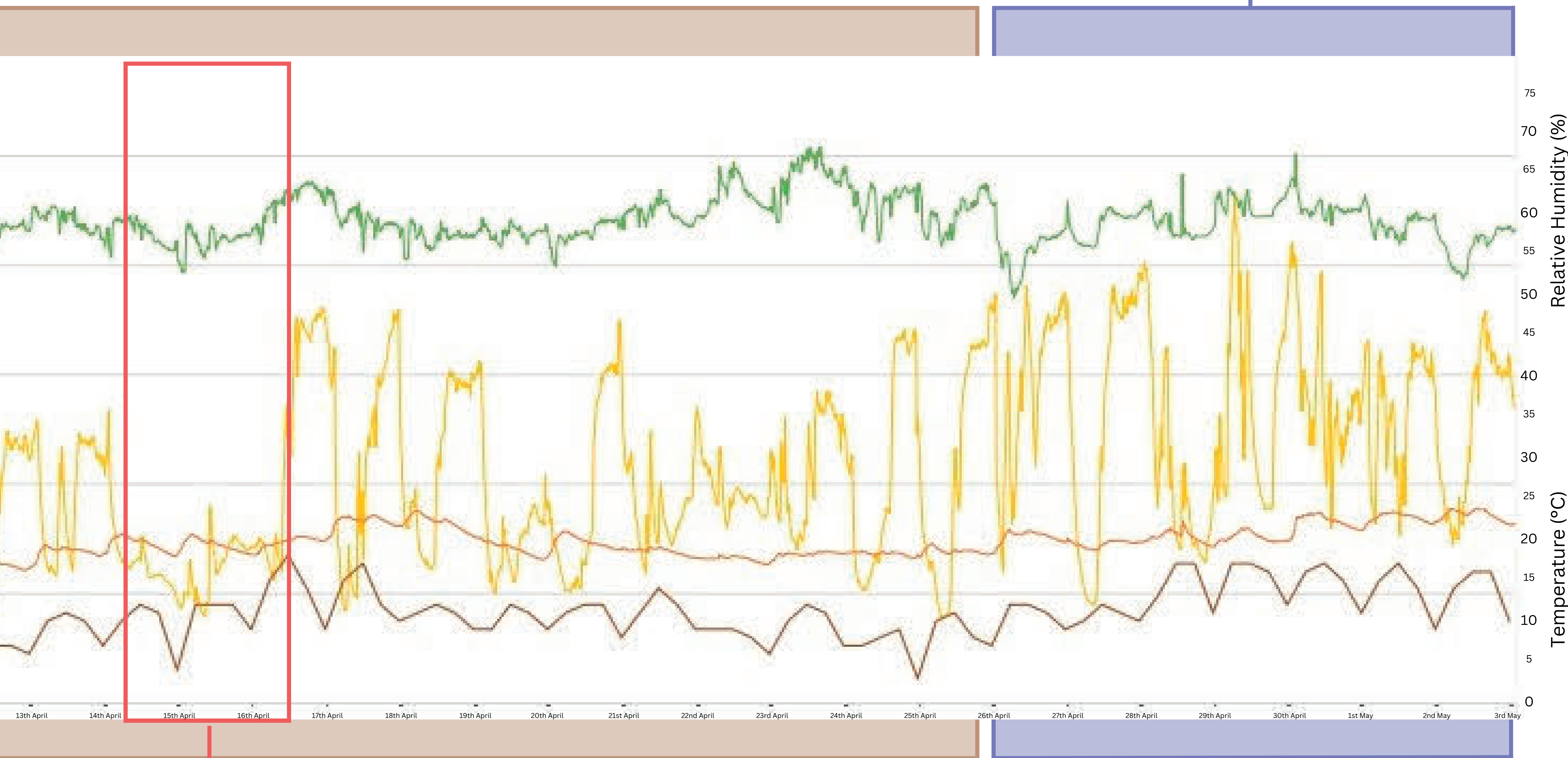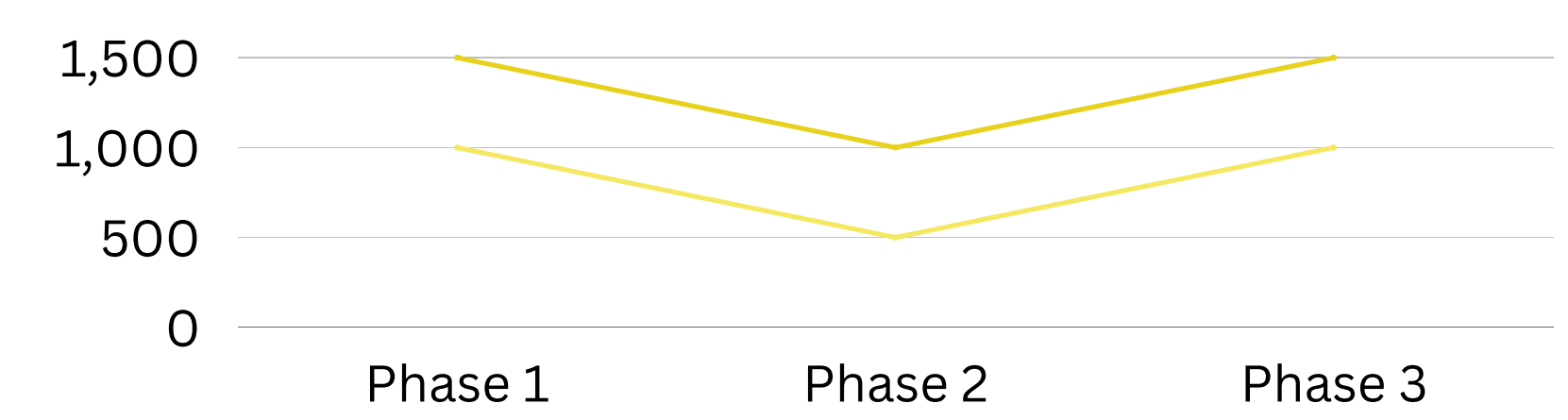
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1. Nephrolepis Boston Blue Bell
2. Chlorophytum Comosum
3. Hedera Green
4. Scindapsus Marble
5. Spathiphyllum
6. Anthurium

Phase 3

Decreased Occupancy

Key Findings

Carbon Dioxide
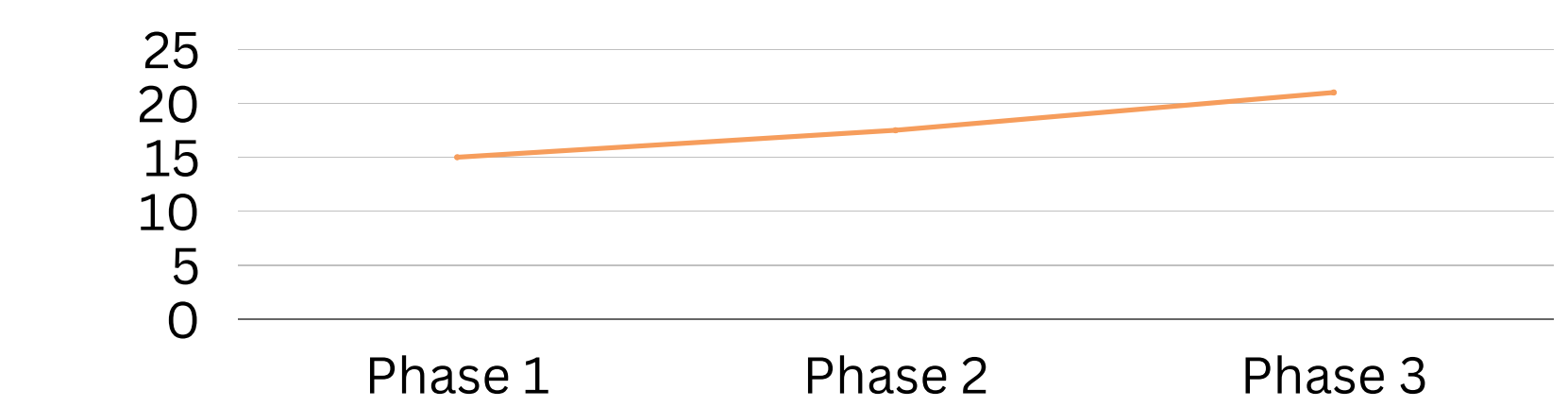Carbon Dioxide Levels were significantly decreased with the presence of the Green Wall throughout Phase 2.

Phase 1 : Peaks 1500-2000ppm / Consistently 1000-1500ppm.
Phase 2 : Peaks 1000-1500ppm / Consistently 500-1000ppm.
Phase 3 : Peaks 1500-2000ppm. Consistentl 1000-1500ppm.

Temperature
Temperature rose steadily across each Phase, although it was more consistent through Phase 2. The Green Wall may have helped to stabilise the temperature, although the rising external temperature throughout the seasons could have caused the overall increase.
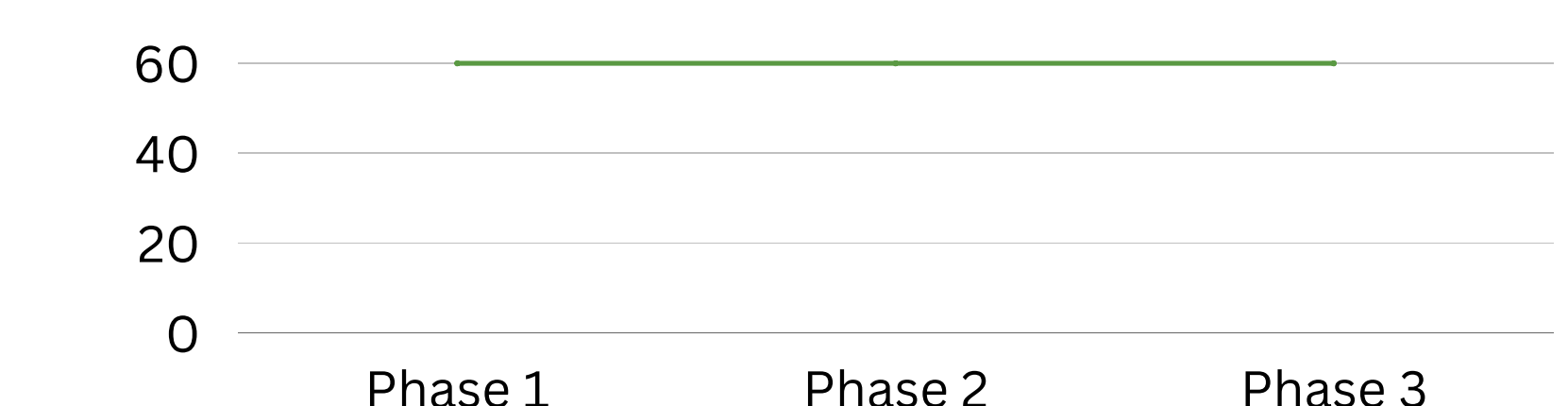
Phase 1 : Between 14-16°C
Phase 2 : Commonly 16-19°C
Phase 3 : Between 19-23°C

Relative Humidity
Relative Humidity was unaffected by the presence of the Green Wall. RH Levels fluctuated slightly within each Phase, but Average and Mode data shows the levels to be consistent across Phases 1, 2 and 3.

Phase 1 : Consistently within 55-65%
Phase 2 : Consistently within 55-65%
Phase 3 : Consistently within 55-65%

Average Values

	CO2 (ppm)	Temp (°C)	RH (%)
Phase 1	1400	16	60.9
Phase 2	1022	18.2	61.2
Phase 3	1322	21.1	58

The average values of each element (CO2, Temp and RH) across each individual phase of testing (Phase 1, 2 and 3)

Mode Values

	CO2 (ppm)	Temp (°C)	RH (%)
Phase 1	1742	14.9	61.3
Phase 2	694	18.6	63
Phase 3	892	19.7	59.3

The mode values of each element (CO2, Temp and RH) across each individual phase of testing (Phase 1, 2 and 3). The mode value is the most common value present in the recorded data.

Limitations
Due to time constraints, Phase 1 and 3 of testing are shorter in favour of gathering more data with the Green Wall present. If this study were to continue, it would be recommended that these Phases also be expnaded upon in order to provide more accurate comparitable data.

Discussion
Levels of Carbon Dioxide were directly affected by the Green Wall, dramatically reducing the amount of CO2 present in the air. The Green Wall brought CO2 levels to down to the recommended levels for indoor air quality (Below 1000ppm) during Phase 2.

The Temperature was largely unaffected. A consistent rise was noted through each phase, although it could be deduced that the Green Wall stabilised the indoor temperature as there is a noticeably abrupt increase at the beginning of Phase 3, when the Green Wall was removed from the test location.

Relative Humidity was unaffected. RH values remained consistent throughout each phase of testing.

Conclusion
In conclusion, the introduction of a Green Wall did have an affect on Indoor Air Quality by altering the recorded elements. Carbon Dioxide levels significantly decreased, Temperature became more stable and consistent, while Relative Humidity was unaffected.

Indoor planting, in the form of Green Walls, directly impacts the quality of indoor air, although further study could be carried out to expand upon this.

Future Research
Future research into the effects of Green Walls on indoor air quality could build on this study. The plants chosen for this study were proven to directly impact concentrations of Volatile Organic Compounds. This work could be enhanced by monitoring the levels of VOC's in a similarly "active" environment, in which a person or persons are present in the test space and performing daily functions such as work and rest.

Alternatively, a similar study could be conducted, forming a Case Study in which the Green Walls effects on Indoor Air Quality are monitored in a workplace. revolving around the daily functions of an office space or similar. This would be of value as it would assess the impacts of a Green Wall in an a highly stressful and busy environment.

Tadgh O' Rourke

An Investigation into the effects of Green Walls on Indoor Air Quality
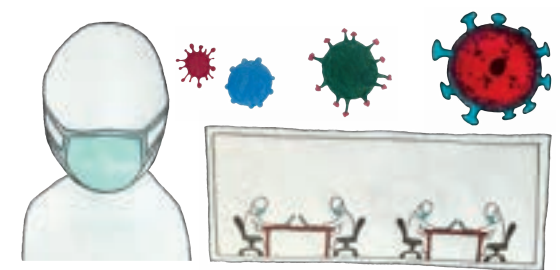
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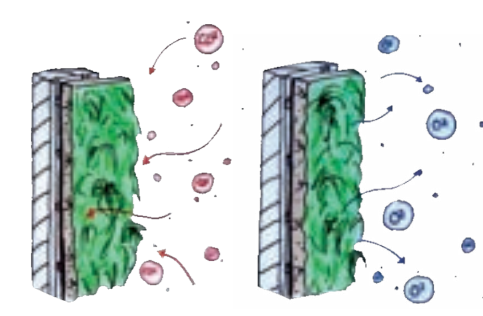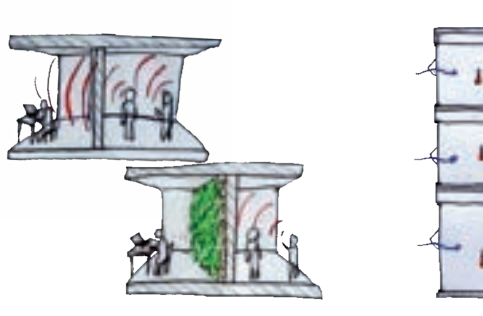
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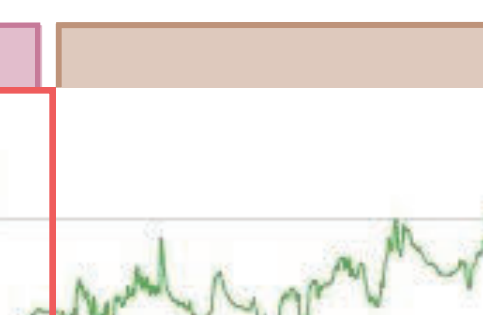
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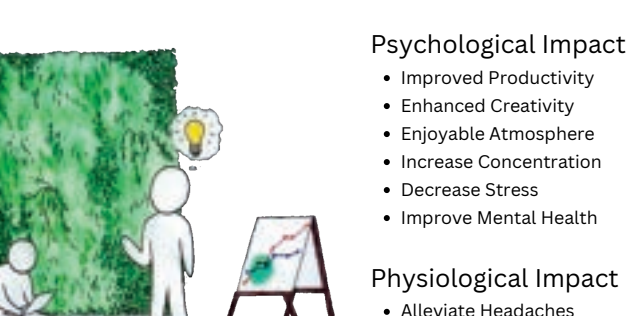
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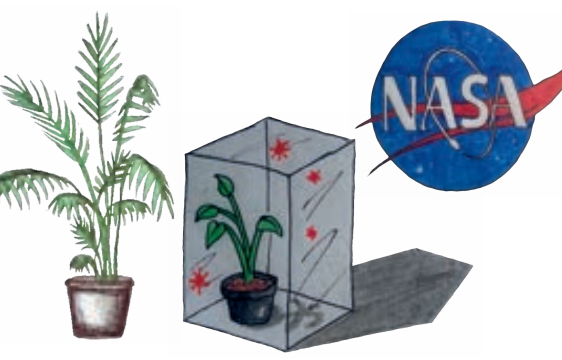
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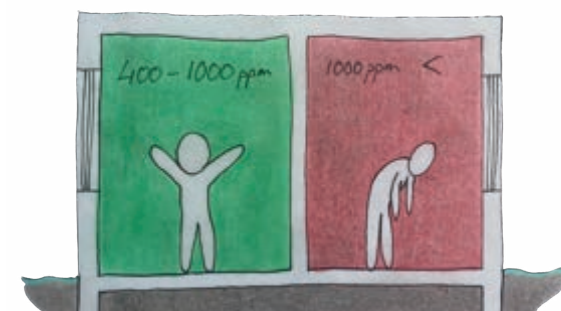- Sore Throat
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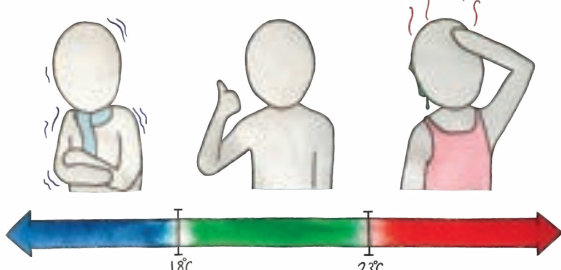
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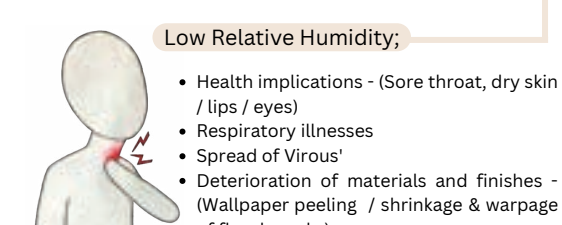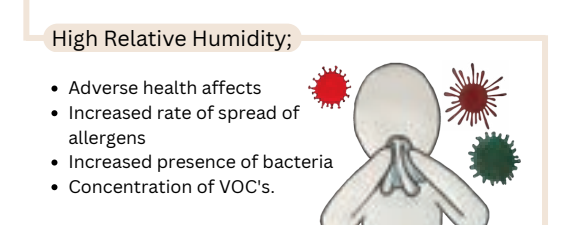Minimum temperatures by Health and Safety Authority;

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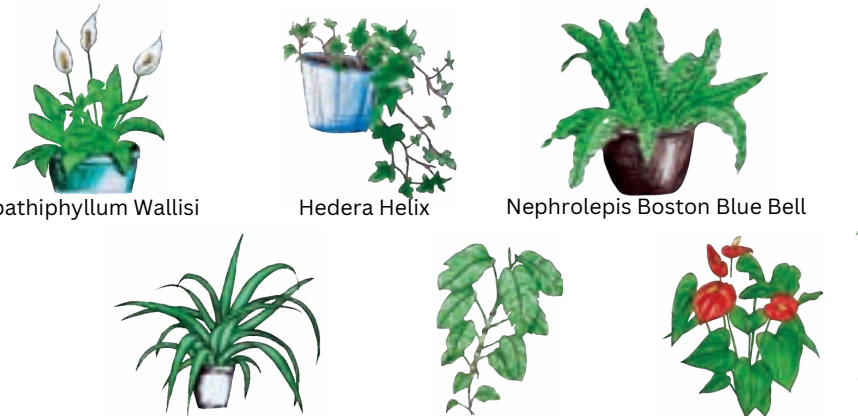- Manual Watering

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The logger features a computer software to record gathered data. The data is displayed as a graphical chart. Charts show all three elements corresponding and can also show elements individually. Data can also be recorded as a text file.

Recorded data is transferred from the data logger to a computer via the attached USB cable. Once attached the computer software can be launched, and data downloaded directly from there.
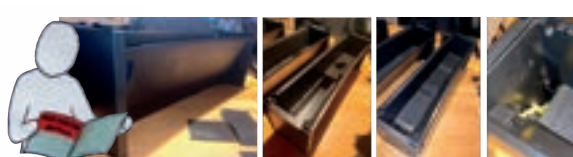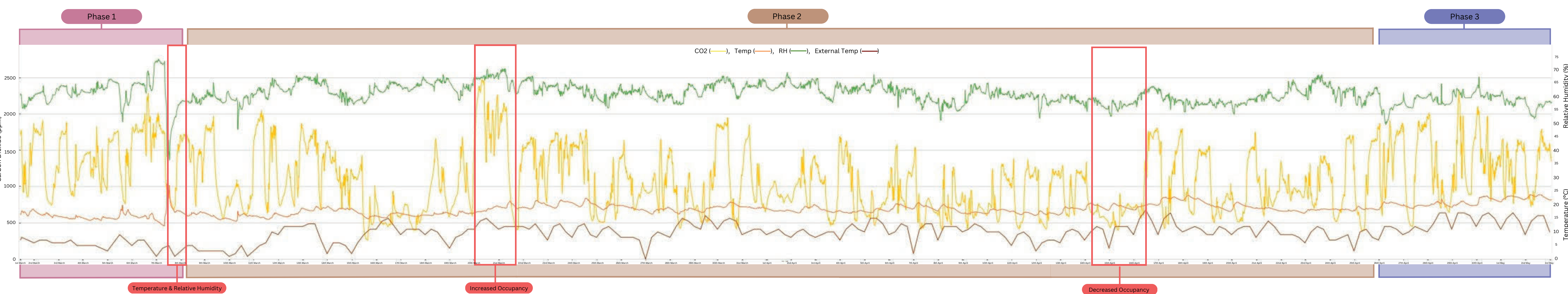

Phase 1 | Phase 2 | Phase 3

CO2 ( ), Temp ( ), RH ( ), External Temp ( )

Temperature & Relative Humidity | Increased Occupancy | Decreased Occupancy

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Testing Phases

Monitoring the following elements to determine the quality of indoor air; Carbon Dioxide (CO2), Temperature (°C) and Relative Humidity (%).

Phase 1 — Pre Room Monitoring

Monitoring the indoor air quality of the test location prior to the installation of the Green Wall prototype. The purpose of this phase is to gain an understanding of the existing air quality in order to create a comparator when the Green Wall prototype is introduced to the location.

Time Period;
1 Week - March 1st 2023 until March 8th 2023

Phase 2 — Green Wall Monitoring

Monitoring the indoor air quality of the test location upon the installation of the Green Wall prototype. The purpose of this phase is to assess if the presence of a Green Wall prototype in the test location does or does not have any impact on the air quality.

Time Period;
7 Weeks - March 8th 2023 until April 26th 2023

Phase 3 — Post Room Monitoring

Monitoring the indoor air quality of the test location upon the removal of the Green Wall prototype. The purpose of this phase is to determine if any changes (if any occurred) during Phase 2 were as a result of the Green Wall prototype and not unseen factors.

Time Period;
1 Week - April 26th 2023 May 3rd 2023

Test Room

South Elevation | North Elevation | East Elevation | West Elevation

Floor Plan
3.75 X 2.85m   11m2 / 115 SF   22.6m3

Furniture Plan

Test Room 3D

Test Conditions

The Door and Window to the room were closed shut at all times, except when the door was used to move in and out of the room. The only source of ventilation is the 14cm X 10cm vent located in the ceiling.

These conditions were kept across all 3 testing phases.

Occupancy Routine

The test location functioned as a workspace during the day, with a rough schedule of 9-5 everyday. The room was then used for leisure and occupied for sleep every night.

These routines were kept across all 3 testing phases.

Key Findings

Carbon Dioxide

Carbon Dioxide Levels were significantly decreased with the presence of the Green Wall throughout Phase 2.

Phase 1: Peaks 1500-2000ppm | Consistently 1000-1500ppm.
Phase 2: Peaks 1000-1500ppm / Consistently 500-1000ppm.
Phase 3: Peaks 1500-2000ppm. Consistent 1000-1500ppm.

Temperature

Temperature rose steadily across each Phase, although it was more consistent through Phase 2. The Green Wall may have helped to stabilise the temperature, although the rising external temperature throughout the seasons could have caused the overall increase.

Phase 1: Between 14-16°C
Phase 2: Commonly 16-19°C
Phase 3: Between 19-23°C

Relative Humidity

Relative Humidity was unaffected by the presence of the Green Wall. RH Levels fluctuated slightly within each Phase, but Average and Mode data shows the levels to be consistent across Phases 1, 2 and 3.

Phase 1: Consistently within 55-65%
Phase 2: Consistently within 55-65%
Phase 3: Consistently within 55-65%

Limitations

Due to time constraints, Phase 1 and 3 of testing were shorter in favour of gathering more data with the Green Wall present. If this study were to continue, it would be recommended that these Phases also be expanded upon in order to provide more accurate compaitable data.

Average Values

	CO2 (ppm)	Temp (°C)	RH (%)
Phase 1	1400	16	60.9
Phase 2	1022	18.2	61.2
Phase 3	1322	21.1	58

The average values of each element (CO2, Temp and RH) across each individual phase of testing (Phase 1, 2 and 3)

Mode Values

	CO2 (ppm)	Temp (°C)	RH (%)
Phase 1	1742	14.9	61.3
Phase 2	694	18.6	63
Phase 3	892	19.7	59.3

The mode values of each element (CO2, Temp and RH) across each individual phase of testing (Phase 1, 2 and 3). The mode value is the most common value present in the recorded data.

Discussion

Levels of Carbon Dioxide were directly affected by the Green Wall, dramatically reducing the amount of CO2 present in the air. The Green Wall brought CO2 levels to down to the recommended levels for indoor air quality (Below 1000ppm during Phase 2.

Temperature was largely unaffected. A consistent rise was noted through each phase, although it could be deduced that the Green Wall stabilised the indoor temperature as there is a noticeably abrupt increase at the beginning of Phase 3, when the Green Wall was removed from the test location.

Relative Humidity was unaffected. RH values remained consistent throughout each phase of testing.

Conclusion

In conclusion, the introduction of a Green Wall did have an effect on Indoor Air Quality by altering the recorded elements. Carbon Dioxide levels significantly decreased, Temperature became more stable and consistent, while Relative Humidity was unaffected.

Indoor planting, in the form of Green Walls, directly impacts the quality of indoor air, although further study could be carried out to expand upon this.

Future Research

Future research into the effects of Green Walls on indoor air quality could build on this study. The plants chosen for this study were proven to directly impact concentrations of Volatile Organic Compounds. This work could be enhanced by monitoring the levels of VOC's in a similarly "active" environment, in which a person or persons are present in the test space and performing daily functions such as work and rest.

Alternatively, a similar study could be conducted, forming a Case Study in which the Green Walls effects on Indoor Air Quality are monitored in a workplace, revolving around the daily functions of an office space or similar. This would be of value as it would assess the impacts of a Green Wall in a highly stressful and busy environment.