

# **Report on Live Trials of Interior Plants at Johnson Controls, London, Aldershot, Waterloo**

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**For  
Johnson Controls**



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## Executive Summary

- The benefits of plants were tested at Johnson Controls to examine their effect on air quality and building users' perceptions of their working environment.
- Evidence exists of the ability of plants to balance indoor relative humidity, remove carbon dioxide and other gases, remove volatile organic compounds (chemicals linked to cancer) and remove airborne particles.
- Evidence is also available of the psychological benefits of plants such as reducing stress, affecting mood and perceived health as well as improving productivity.
- Prior to the trials, relative humidity at Cannon Street and The Briars was around 38 - 40% (recommended levels are 40 – 70%), increasing the risk of health disorders such as asthma and eczema. Carbon Monoxide levels were well within recommended levels and carbon dioxide was found to be slightly above maximum recommended levels of 1000 ppm.
- Plants were installed for six months for the trials. Indoor air quality readings were taken and staff surveys completed at Cannon Street, Tower One and The Briars. Staff perceptions were measured using questionnaires.
- Humidity was slightly higher on the floor with plants at Aldershot. At The Briars, an upward trend was noted following the installation of the plants and then readings for the two areas were closer, perhaps due to the open plan nature of the building. A linear increase to within recommended levels was also noted at Cannon Street. This supports the theory that plants raise the humidity level within offices.
- Contrary to expectations, carbon dioxide was found to be slightly higher on the floor with the plants at Tower One. The results followed the same pattern at The Briars while at Cannon Street, the carbon dioxide level increased over the period of the trials. These results are currently unexplained and are not in line with the findings on other trial sites.

- Carbon monoxide, although increasing slightly at Tower One, did follow the expected pattern at The Briars and Cannon Street in that it reduced following the introduction of the plants. The data provides tentative support for the theory that plants reduce carbon monoxide levels in offices.
- Volatile organic compound (VOC) levels reduced over the period of the trials at all three locations. The data provides some support for the theory that plants reduce volatile organic compound levels, although in some cases the figures were slightly lower in the areas without plants.
- Online surveys were used to examine users' perceptions of their workplace. The response rates were relatively low. In the office with plants and a view of natural surroundings, respondents found their office more comfortable, better designed and laid out and felt slightly less pressure than they did in the office without plants. They also perceived that privacy levels had increased, as well as creativity and they felt that the office with plants was more aesthetically pleasing.
- However, there was an increase in the feeling that the work environment contributed to pressure felt and motivation appeared to be slightly lower in the second survey, after the plants were installed.
- The majority of respondents in both surveys indicated that they would like more plants in their offices.
- The results relating to temperature were inconclusive and reflect the subjective nature of this parameter.
- Following the surveys, support was found for a general preference for plants in the office.
- These results may be due to a range of factors, but they provide an indication that plants are likely to bring both air quality and psychological benefits to the working environment. It would be beneficial, therefore, to install living plants in all office areas.

# Contents

Distribution List .....	2
Executive Summary .....	2
Contents .....	4
Background .....	5
Objectives .....	5
Introduction.....	5
The Benefits of Plants .....	6
Physical Benefits: Air Quality .....	6
Balancing indoor relative humidity .....	6
Removal of Carbon Dioxide (CO <sub>2</sub> ).....	6
Removal of Volatile Organic Compounds (VOCs).....	6
Removal of airborne particles.....	7
Psychological Benefits.....	8
Air quality at Johnson Controls prior to the trials.....	9
Plant trial details .....	10
Results.....	11
Indoor Air Quality.....	11
Relative Humidity .....	11
Carbon Dioxide and Carbon Monoxide.....	16
Volatile Organic Compounds (VOCs).....	24
User Perceptions .....	28
Survey 1 .....	28
Survey 2 .....	30
Comparison of Farnborough and Aldershot results for surveys 1 and 2 .....	31
General comments .....	32
Conclusions.....	35
Recommendation .....	36
Appendix 1 – Average Temperatures .....	37

## Background

Liverpool John Moores University is undertaking research funded by the DTI and GP Plantscape Ltd. GP Plantscape is an interior and exterior "plantscaping" organisation that works with FM companies to deliver a better working environment. GP has taken steps to develop a new interior high end plantscape product through a business research partnership with JMU.

The project examines the nature of the plant based interior design operation within the corporate environment and will offer an optimum solution within high end buildings and organisations.

Johnson Controls have offered the use of their offices at Cannon Street, London; Tower One, Aldershot and The Briars, Waterlooville for trials into the benefits of plants in office environments. The trials were run by Liverpool John Moores University and GP Plantscape Ltd.

## Objectives

- Test the effect of interior planting on indoor air quality
- Test the effect of interior planting on occupant perceptions of privacy, aesthetics, stress levels and productivity
- Test the effect of interior planting on short term sickness rates
- Test the effect of interior planting on building-related health complaints
- Test the effect of interior planting on occupant productivity
- Provide a report to Johnson Controls detailing the results of the trials
- Demonstrate the link between interior planting and corporate profitability

## Introduction

With evidence that employee disengagement is increasing<sup>1</sup>, it is important to provide workplaces that positively influence the workforce. The focus is often on symptoms of disengagement such as distraction, lack of interest, poor decisions and high absence, rather than the root causes. The working environment is perhaps a key root cause in employee engagement or disengagement.

Research has indicated that improving the working environment reduces complaints and absenteeism and increases productivity<sup>2</sup>. Workplace satisfaction has been associated with job satisfaction and perceptions of workplace quality have a significant effect on building users' psychology.

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<sup>1</sup> Pech, R., Slade, B. (2006) "Employee disengagement: Is there evidence of a growing problem?", Handbook of Business Strategy, Vol. 7 No. 1, pp. 21-25.

<sup>2</sup> Roelofsen, P. (2002) "The impact of office environments on employee performance: The design of the workplace as a strategy for productivity enhancement", Journal of Facilities Management, Vol. 1 No. 3, pp. 247-264.

# The Benefits of Plants

## ***Physical Benefits: Air Quality***

### Balancing indoor relative humidity

Low relative humidity is associated with dry air, causing skin complaints, asthma, irritation of mucous membranes and frequent colds among building users. While heating and air conditioning systems can control humidity by stripping moisture from the air, they cannot raise humidity by adding moisture<sup>3</sup>. Humidifiers are also not ideal as they use energy and require regular maintenance and cleaning.

The use of plants in pebble-filled trays and adding water has been recommended because one of the many substances emitted by plants is water vapour<sup>1</sup>.

During trials of plants impacting on particulate accumulation, relative humidity was found to be higher when plants were present than when they were not<sup>4</sup>.

It has been suggested that plants may be used instead of humidifiers to add moisture to homes and offices through transpiration. In one study<sup>5</sup>, a sunroom containing plants had significantly higher humidity levels than a bedroom containing no plants.

### Removal of Carbon Dioxide (CO<sub>2</sub>)

The ability of indoor plants to remove carbon dioxide has been well documented. This ability is useful for indoor environments as carbon dioxide can cause tiredness and lethargy among building occupants.

During photosynthesis, plants absorb carbon dioxide from the atmosphere through the stomata (tiny openings on the leaves), while the roots absorb moisture from the soil. Chlorophyll and other tissue in the leaves absorb radiant energy from a light source, which is used to split water molecules into oxygen and hydrogen. Hydrogen and carbon dioxide are used by the plant to form sugars, while oxygen, a by-product of photosynthesis is released into the atmosphere<sup>1</sup>.

### Removal of Volatile Organic Compounds (VOCs)

Much of the research into the effects of indoor plants on air quality was carried out during the 1980s in the United States by Bill Wolverton and his team during research for NASA into space stations and energy efficient buildings on earth. The NASA

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<sup>3</sup> Wolverton, B.C. (1996) *How to grow fresh air: 50 houseplants that purify your home or office*. Weidenfeld and Nicolson, London.

<sup>4</sup> Lohr, V.I., Pearson-Mims, C.H. (1996) "Particulate matter accumulation on horizontal surfaces in interiors: Influence of foliage plants." *Atmospheric Environment*, Vol. 30, No. 14, pp. 2565 – 2568.

<sup>5</sup> Wolverton, B.C., Wolverton, J.D. (1996) "Interior plants: Their influence on airborne microbes inside energy-efficient buildings." *Journal of the Mississippi Academy of Sciences*, Vol. 41, NO. 2, pp. 99 – 105.

research focused on the ability of plants to remove pollutants from air and water. NASA researched the issue for over 15 years.

Based on their research, NASA scientists have recommended the use of indoor plants to purify the air in sealed energy-efficient homes<sup>6</sup>.

NASA carried out experiments using a modular structure separated into two rooms, one side being used as a control while plants were placed in the other side. The studies conducted in the modular structure demonstrated a dramatic reduction in air pollution in the side containing the plants while a large number of air pollutants remained in the side without plants<sup>7</sup>.

NASA found that the roots and associated micro-organisms were more important in removing chemicals than had previously been understood. They concluded, therefore, that the plant is very important in removing indoor air pollution either directly through the leaves or indirectly through the root/soil pathway<sup>8</sup>.

Other studies have lent support to the NASA findings. In one study, spider plants were put in contact with formaldehyde over a period of 24 hours and the formaldehyde was removed from the atmosphere of the experimental glass chamber by the plants within 5 hours to below the detection limit. The results suggested that a single 300g spider plant could detoxify a 100 cubic metre room in six hours<sup>9</sup>.

### Removal of airborne particles

Plants also have the ability to remove airborne particles such as dust or more harmful particles, found in a recent study to be emitted in high quantities from office printers<sup>10</sup>. Many studies have shown evidence that outdoor vegetation such as trees and shrubs reduce atmospheric dust but indoor plants also display this characteristic. Plants act as natural filters, causing particles to be deposited on the vegetative surface through sedimentation, impaction or precipitation<sup>11</sup>. Vegetation with rough surfaces

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<sup>6</sup> Wolverton, B.C., McDonald, R.C. (1982) "Foliage plants for removing formaldehyde from contaminated air inside energy-efficient homes and future space stations."  
[http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19860065907\\_1986065907.pdf](http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19860065907_1986065907.pdf)

<sup>7</sup> Wolverton, B.C. (1988) "Foliage plants for improving indoor air quality."  
[http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19930073015\\_1993073015.pdf](http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19930073015_1993073015.pdf)

<sup>8</sup> Wolverton, B.C., Douglas, W.L., Bounds, K. (1989) "A study of interior landscape plants for indoor air pollution abatement: An interim report."  
[http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19930072988\\_1993072988.pdf](http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19930072988_1993072988.pdf)

<sup>9</sup> Giese, M., Bauer-Doranth, U., Langebartels, C., Sandermann Jr., H. (1994) "Detoxification of formaldehyde by the spiderplant (*Chlorophytum comosum* L.) and by soybean (*Glycine max* L.) cell-suspension cultures," *Plant Physiology*, Vol. 104, pp. 1301 – 1309.

<sup>10</sup> He, C., Morawska, L., Taplin, L. (2007) "Particle emission characteristics of office printers", *Environmental Science and Technology*, Vol. 41, No. 17, pp. 6039 – 6045.

<sup>11</sup> Lohr, V.I., Pearson-Mims, C.H. (1996) "Particulate matter accumulation on horizontal surfaces in interiors: Influence of foliage plants." *Atmospheric Environment*, Vol. 30, No. 14, pp. 2565 – 2568.

from fine hairs or raised veins for example, is more efficient in reducing airborne particulates than smooth vegetation<sup>9</sup>.

In one study<sup>9</sup>, plant trials were carried out in a computer laboratory and an office. The results showed that in the computer lab, particulate matter was lower in the presence of plants than in their absence and particulate matter accumulation was also substantially lower in the office space when plants were present than when they were absent, indicating that plants reduce particulates in interior spaces.

## ***Psychological Benefits***

A range of literature exists regarding the psychological benefits that plants bring to occupants of indoor environments, particularly in healthcare settings. Until relatively recently, little attention had been given to the role of nature in the workplace.

In interviews of office workers, it was found that the use of large plants appeared to increase the individual's sense of privacy. The interviewees concurred that the office was more pleasant and informal with plants and that this appeared to reduce their need for a high level of privacy<sup>12</sup>.

Privacy and distraction are some of the main areas of complaint about working environments but there are positive distractions, such as trees, plants and water that may be incorporated into buildings to improve workplace quality, privacy and productivity<sup>13</sup>.

One study found that peoples' mood may be affected by plants<sup>14</sup>. It was also found that plants can be used to influence spatial perceptions outdoors in that smaller trees and light texture can be used to enlarge an open space while large trees with coarse texture have the opposite effect<sup>15</sup>. These results may be relevant to the indoor environment in the selection of office plants.

Another study asserted that those with a view of nature such as trees and greenery were more satisfied and that even a short exposure to a natural setting can serve a restorative function. The report stated that: 'Those with a view of nature felt less

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<sup>12</sup> Goodrich, R. (1982), "The Perceived Office: The Office Environment as Experienced by its Users", in: Wineman, J. (1986) Behavioral Issues in Office Design, Van Nostrand Reinhold, New York, pp. 109-133.

<sup>13</sup> James, P. (2007), "Indoor green space: influences your health", available at: <http://www.rgc.salford.ac.uk/peterbarrett/p/?s=10&pid=6>

<sup>14</sup> Shibata, S., Suzuki, N. (2002) "Effects of the foliage plant on task performance and mood", Journal of Environmental Psychology, Vol. 22 No. 3, pp. 265-272.

<sup>15</sup> Serpa, A. Muhar, A. (1996) "Effects of plant size, texture and colour on spatial perception in public green areas – a cross-cultural study", Landscape and Urban Planning, Vol. 36 No. 1, pp. 19-25.



frustrated and more patient, found their job more challenging, expressed greater enthusiasm for it, and reported higher life satisfaction as well as overall health'<sup>16</sup>.

The same study suggested that having natural areas at the workplace can be useful for views or direct involvement such as lunch areas and areas to walk. Bringing nature into buildings is becoming increasingly popular with the use of landscaped atria and “streets” within buildings.

Further support for workplace plants was added by a study finding that office plants increased participants' perceptions of office attractiveness and comfort<sup>17</sup>.

A general preference for offices with plants compared to offices without plants has also been identified<sup>18</sup>

## **Air quality at Johnson Controls prior to the trials**

An air quality check was carried out at Cannon Street and The Briars prior to the plants being installed. However, it was not possible to check the air quality at Tower One before the installation of the plants.

At Cannon Street the humidity level was around 38-39% RH, slightly below the minimum recommended level of 40%. This could increase the risk of health disorders among sensitive individuals, such as asthma and eczema sufferers, where dry nasal membranes and skin tissue reduces the protection afforded against sensitising agents. At The Briars, humidity was recorded at around 40% although it is desirable to raise the level slightly to ensure it is within recommended humidity levels.

Although change is desirable, there are often no humidity controls within office areas so alternative approaches to the building management system often need to be considered.

Carbon Monoxide (CO) levels at both sites were found to be well below the recommended maximum safe levels at around 0.3 - 0.4 ppm at Cannon Street and 0.2 - 0.3 ppm at The Briars.

Carbon Dioxide (CO<sub>2</sub>) levels were found to be slightly higher than the recommended maximum of 1000 ppm for offices. The CO<sub>2</sub> level was found to be around 1000 – 1100 ppm at Cannon Street and 1200 – 1300 ppm at The Briars. This can cause tiredness and lethargy among building occupants so it is desirable to lower this to as low a level as possible under 1000 ppm.

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<sup>16</sup> Kaplan, R. (1993) “The role of nature in the context of the workplace”, *Landscape and Urban Planning*, Vol. 26 No. 1-4, pp. 193-201.

<sup>17</sup> Larsen, L., Adams, J., Deal, B., Kweon, B., Tyler, E. (1998) “Plants in the workplace: The effects of plant density on productivity, attitudes and perceptions”, *Environment and Behavior*, Vol. 30 No. 3, pp.261-281.

<sup>18</sup> Smith, A., Pitt., M (2008) “Preference for plants in an office environment”, *Proceedings of CIB W70 Conference on Facilities Management*, Edinburgh, June 2008.

Table 1 shows the results of the initial air quality assessment at Cannon Street and The Briars.

Table 1: Air quality assessment results – 02/04/08

<b>Location</b>	<b>Air Temperature (°C)</b>	<b>Relative Humidity (%RH)</b>	<b>Carbon Dioxide (ppm)</b>	<b>Carbon Monoxide (ppm)</b>
Cannon Street	21.5	38.9	1092	0.3
Cannon Street	21.3	38.7	1099	0.4
Cannon Street	21.5	39.0	1124	0.4
Cannon Street	21.3	39.2	1139	0.4
Cannon Street	21.3	39.2	1159	0.4
The Briars, Accounts Payable	24.3	40.2	1294	0.3
The Briars, Accounts Payable	24.3	40.4	1297	0.3
The Briars, Accounts Payable	24.2	40.0	1284	0.3
The Briars, Call Centre	24.2	40.4	1220	0.3
The Briars, Call Centre	24.2	40.7	1210	0.2
The Briars, Call Centre	24.2	40.9	1209	0.2

It was decided to trial indoor plants to balance the humidity naturally and improve air quality.

## **Plant trial details**

The offices used for the plant trials were Cannon Street, London, floors 1 and 2 of Tower One, Aldershot and the first floor call centre at The Briars, Waterlooville. The offices at Aldershot and Waterlooville were selected to have two offices of the same

orientation and size, occupied by approximately the same number of people, doing similar jobs.

Live interior plants were provided on the second floor of Tower One, on one side of the first floor at The Briars and at Cannon Street by GP Plantscape Ltd for a period of six months from May to the end of October 2008. These were installed and maintained free of charge for the period of the trials. Quotations were also provided by GP Plantscape to show what plants were supplied and the rental costs if these were being provided under a paying contract.

The plants provided were soil-grown plants of standard varieties normally used by GP Plantscape for office environments.

In order to measure the difference made by the plants, measurements were taken in the following areas:

- Air Quality
- Staff perceptions of privacy, aesthetics, stress levels and productivity
- Short term sickness rates
- Building related health complaints

Air quality was tested using an air quality monitor on an approximately fortnightly basis. Checks were carried out for humidity, carbon dioxide and carbon monoxide. Additional checks were completed for total volatile organic compound concentrations.

Staff perceptions were measured using a questionnaire, completed twice during the period of the trials by staff based at all three locations. The first pass of the survey was completed prior to the plants being installed and it was administered again after the installation of the plants.

## **Results**

### ***Indoor Air Quality***

#### **Relative Humidity**

Relative humidity was measured using a Graywolf IAQ monitor on an approximately fortnightly basis. At Cannon street, measurements were taken in various locations around the one floor occupied by Johnson Controls. At Tower One and The Briars, measurements were taken in two separate areas, one with plants and one without plants.

The results were compared, with the expectation that the presence of plants would increase humidity levels so that the humidity level in those areas with plants would be higher than that of those areas without plants.

Figure 1 shows a comparison of humidity on the first floor at Tower One (without plants) compared to the second floor (with plants) from June to September 2008. This graph shows that the humidity levels on the second floor were generally higher than

those of the first floor over the period of the trials, as expected. Although there were peaks and troughs, the humidity level was within the recommended range of 40 – 60% for the trial period. However, on one visit the humidity level on the floor without plants dropped below the recommended minimum of 40%, while on the floor with plants, it was maintained above 40%.

At The Briars, the results for humidity were much closer across the two areas used than at Tower One. Due to the open plan nature of the areas used at The Briars, it is likely that the air quality in the area without plants was affected by that of the area with plants. Again, there were peaks and troughs but the data shows an upward trend following the introduction of the plants. The results are shown in figure 2.

An analysis of the data for Cannon Street helps to establish the humidity benefits of plants. Figure 3 shows the average humidity from April to September 2008. This is an average of the five readings taken in each area of Cannon Street during the visit.

This graph shows that, although there are peaks and troughs again, a linear increase in humidity levels has occurred since the plants were installed. This has taken the humidity to within the recommended level of 40-60% RH. This showed a steeper rise than at the other two sites following the introduction of plants, before levelling out at around 50% relative humidity, which is around the midpoint of the recommended humidity range.

This data supports the theory that plants raise the humidity level within offices.

Figure 1: Average Humidity, Tower One – 1<sup>st</sup> (without plants) and 2<sup>nd</sup> Floor (with plants)

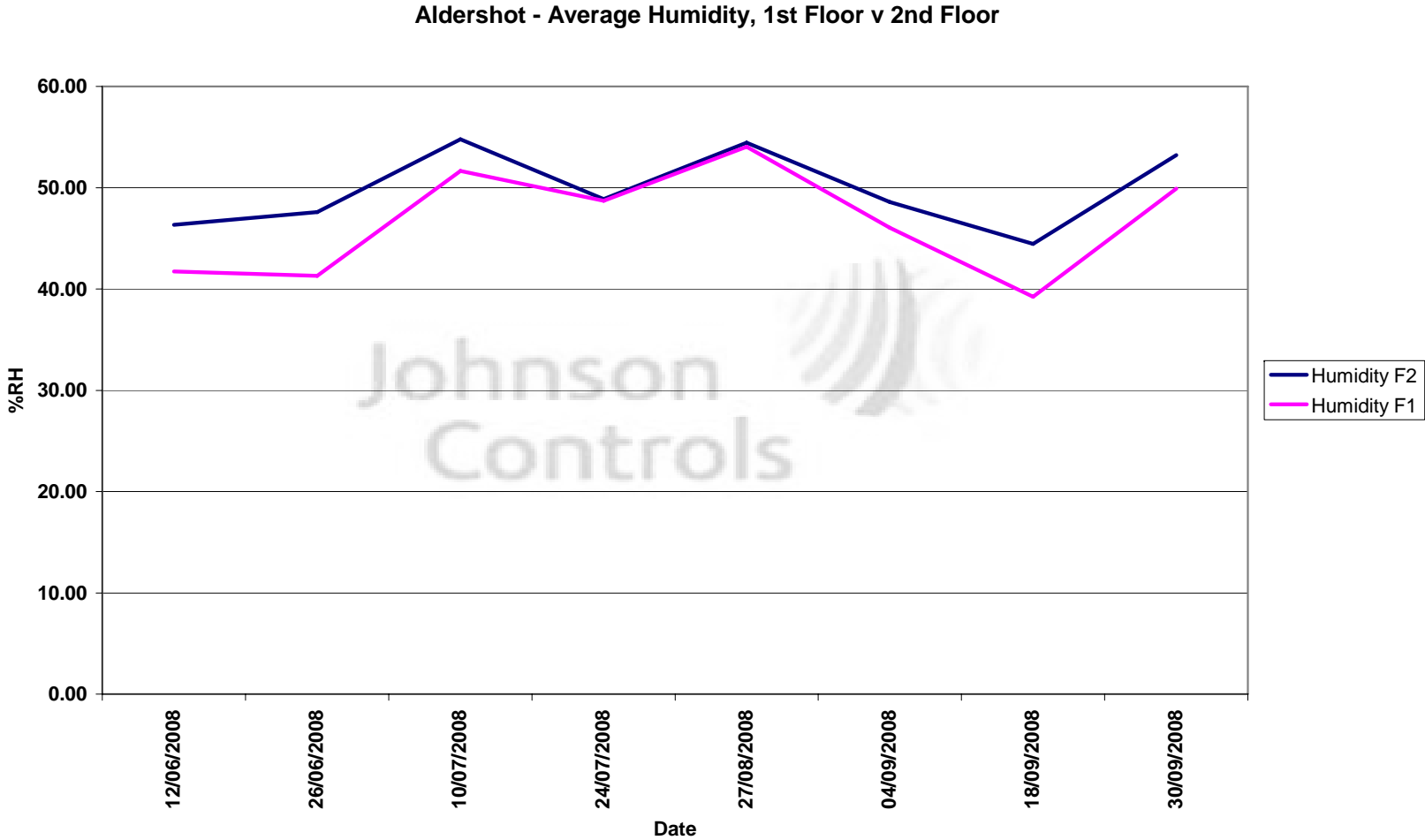


Figure 2: Average Humidity, The Briars – Call Centre (without plants) and Accounts Payable (with plants)

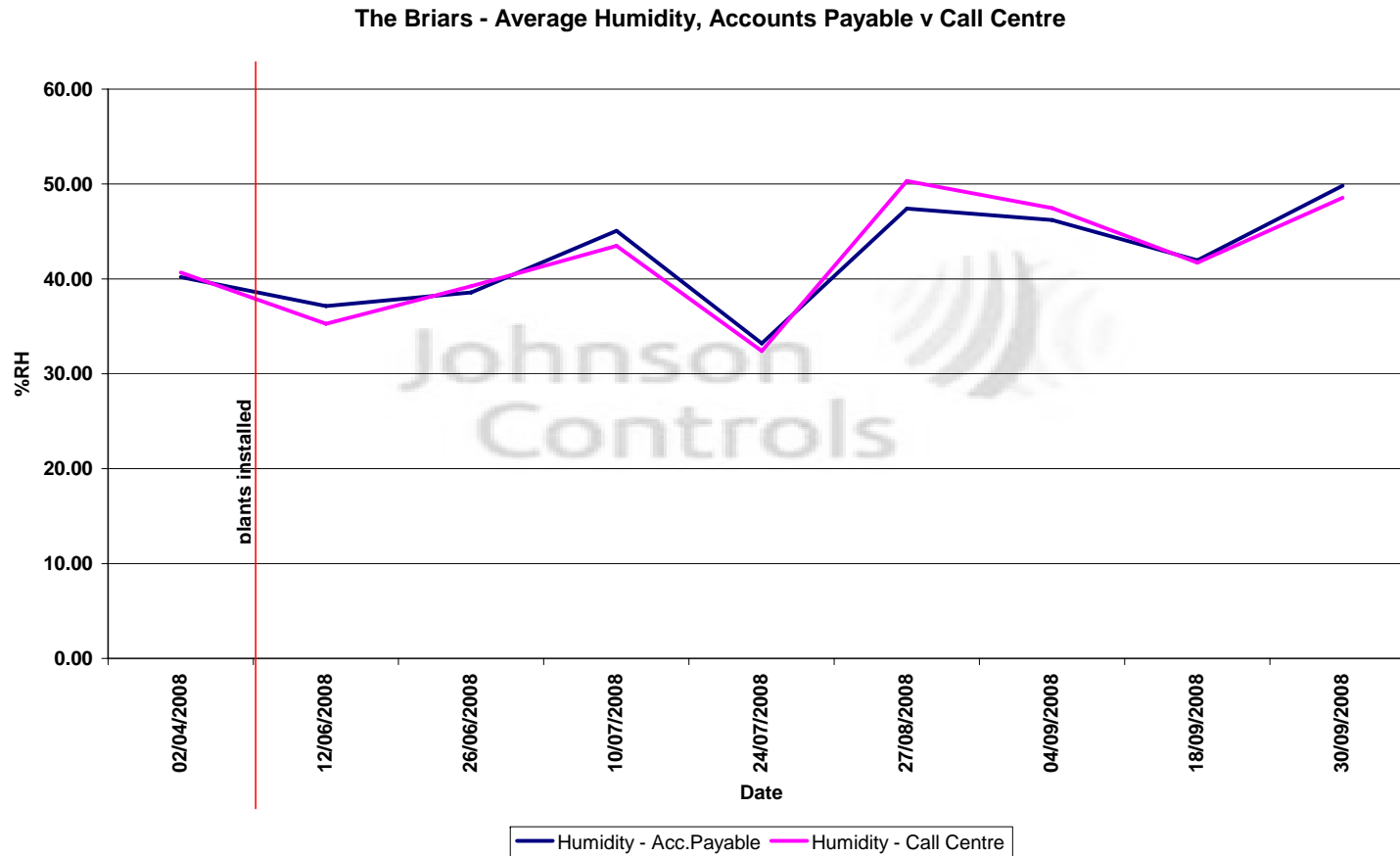
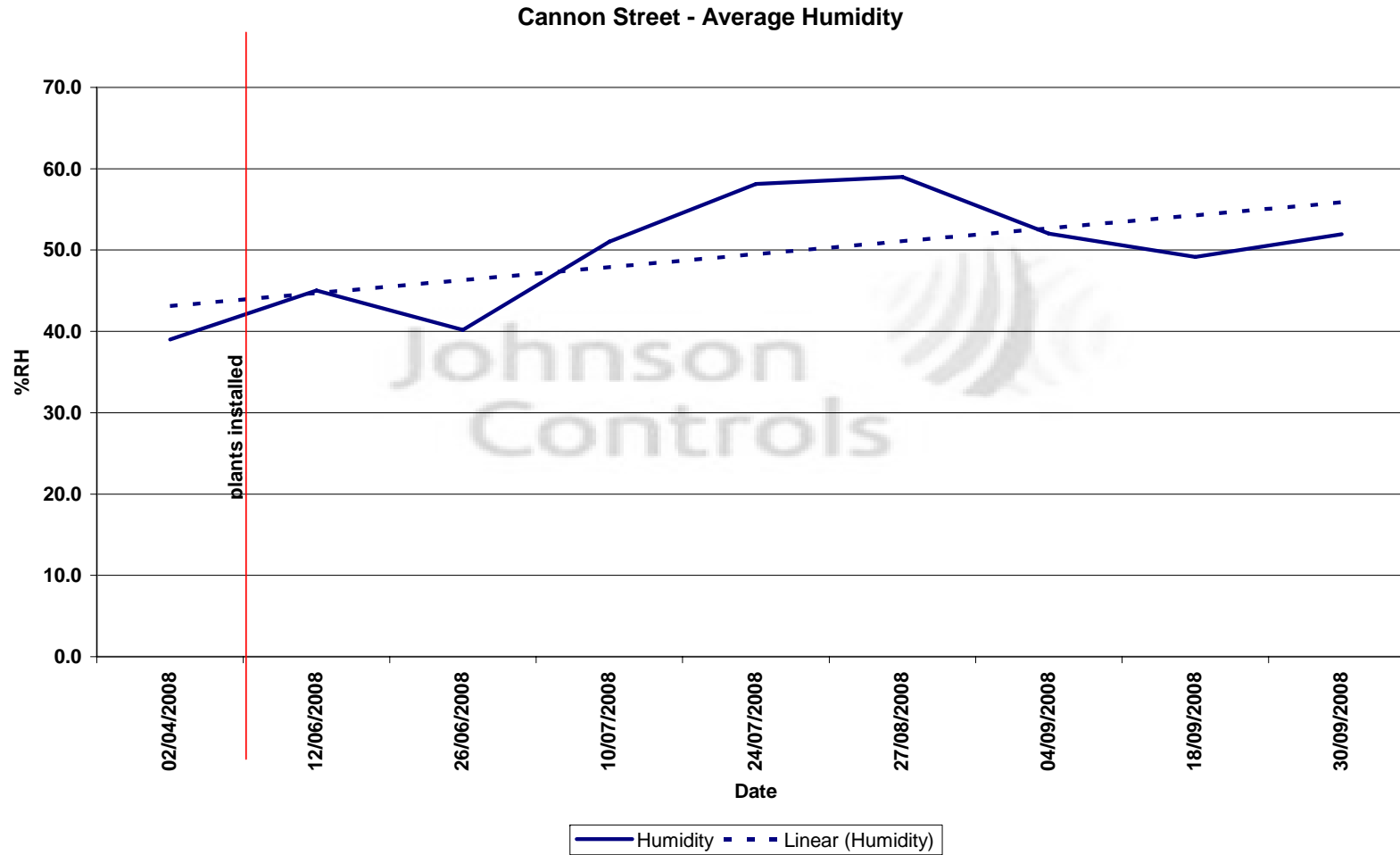


Figure 3: Average Humidity, Cannon Street



## Carbon Dioxide and Carbon Monoxide

Carbon Dioxide (CO<sub>2</sub>) and Carbon Monoxide (CO) were measured using a Graywolf IAQ monitor. Approximately fortnightly measurements were taken using the Graywolf monitor within the offices at Cannon Street, Tower One and The Briars.

The results were compared, with the expectation that the presence of plants would reduce the levels of Carbon Dioxide and Carbon Monoxide so that the levels of these gases in areas with plants would be lower than those of areas without plants.

Figure 4 shows a comparison of carbon dioxide levels for the first and second floor at Tower One from June to September 2008. Contrary to expectations, the carbon dioxide level is slightly higher on the second floor (where the plants are located), compared to the first floor for the majority of the trial period. This result currently remains unexplained.

Figure 5 shows the data on carbon dioxide for The Briars, where levels were compared between the call centre and accounts payable areas of the first floor. Carbon dioxide levels remained relatively constant in both areas during the period of the trials but, as with Aldershot, carbon dioxide was found to be higher in the area with plants than in the area without plants. This does not follow the expected pattern. As with humidity, it is possible that the air quality in the non-planted area was affected by the plants on the other side of the office. As carbon dioxide is generated by human breath and talking, it is also likely that levels will be higher in call centre environments. Further research would be required to establish the full reasons for this anomaly.

At Cannon Street, results for carbon dioxide were also contrary to the expected pattern. Figure 6 shows a linear increase in the CO<sub>2</sub> level following the introduction of the plants. However, the level did decrease significantly to around half its starting point around the mid stage of the trials. The reasons for it then rising again are unexplained and further research would be required to establish reasons for this.

This data does not, therefore, support the theory that the plants would have a beneficial effect on the carbon dioxide levels within the Johnson Controls offices. This is contrary to previous research by other authors and the results found during trials with another organisation.

The average carbon monoxide level actually increased slightly over the period of the trials at Aldershot and the increase was slightly steeper on the floor with plants. Again, this was against expectations, but the levels observed were very small and well below recommended maximum levels. The average level increased from around 0.05 ppm to a peak of around 0.15 ppm before dropping towards its starting level on the floor with plants. This is shown in figure 7.

At The Briars, the results for carbon monoxide were more in line with expectations. The average carbon monoxide level decreased in both areas over the period of the trials and the area where the plants are installed experienced a steeper decrease. It appears that the plants in one area may have affected the air quality in the non-planted area, in line with the other results obtained.



A downward trend in carbon monoxide levels was also experienced at Cannon Street over the trial period. However, the peaks and troughs were greater there, with a drop from around 0.4 ppm to 0.1 ppm before rising again to around 0.4 ppm, for example. However, by the end of the trial, the level to around 0.2 ppm, which is about half its starting value.

This data does, therefore, provide tentative support for the theory that plants reduce carbon monoxide levels in offices.

Figure 4: Average Carbon Dioxide Levels, Tower One – 1<sup>st</sup> Floor (without plants) and 2<sup>nd</sup> Floor (with plants)

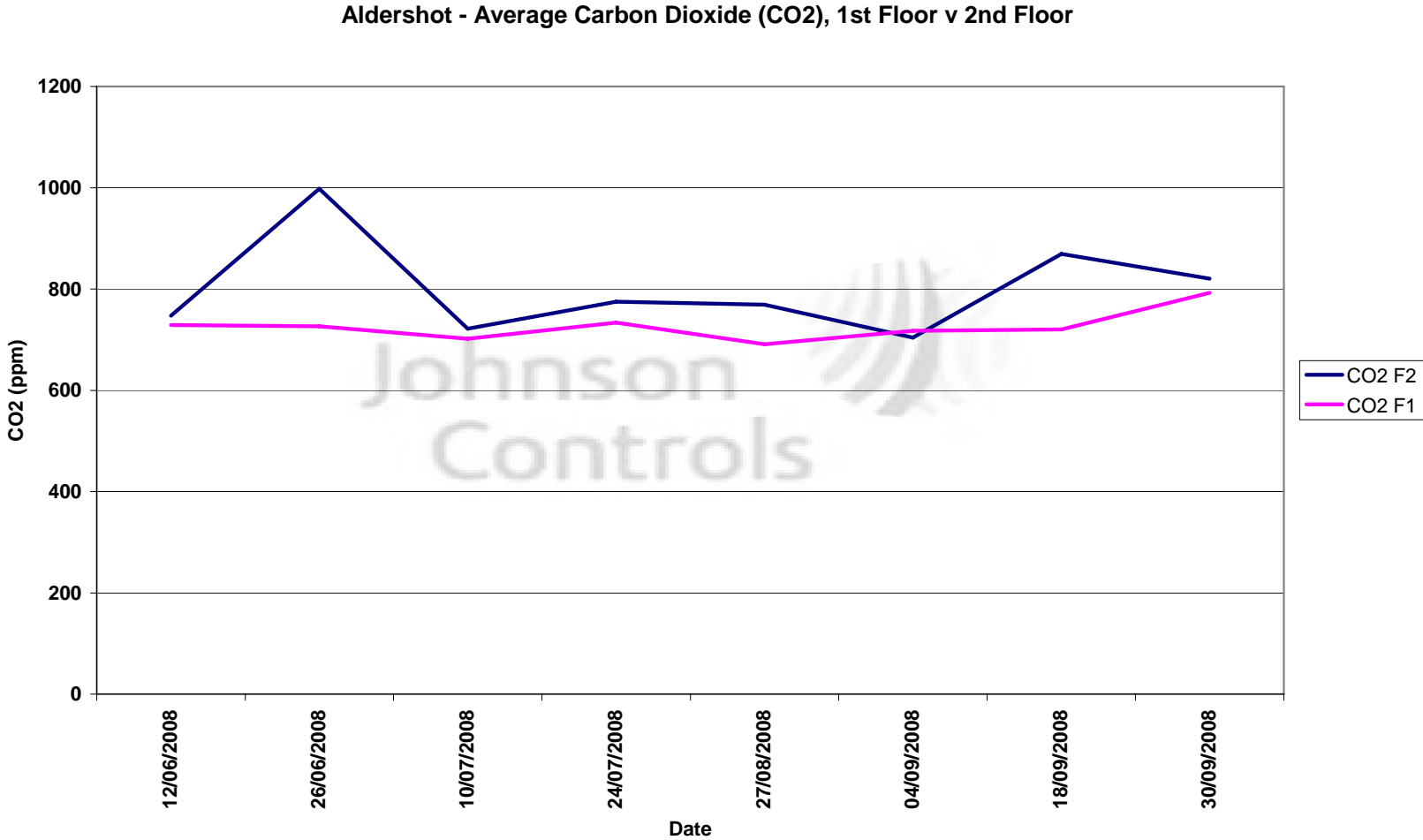


Figure 5: Average Carbon Dioxide Levels, The Briars – Call Centre (without plants) and Accounts Payable (with plants)

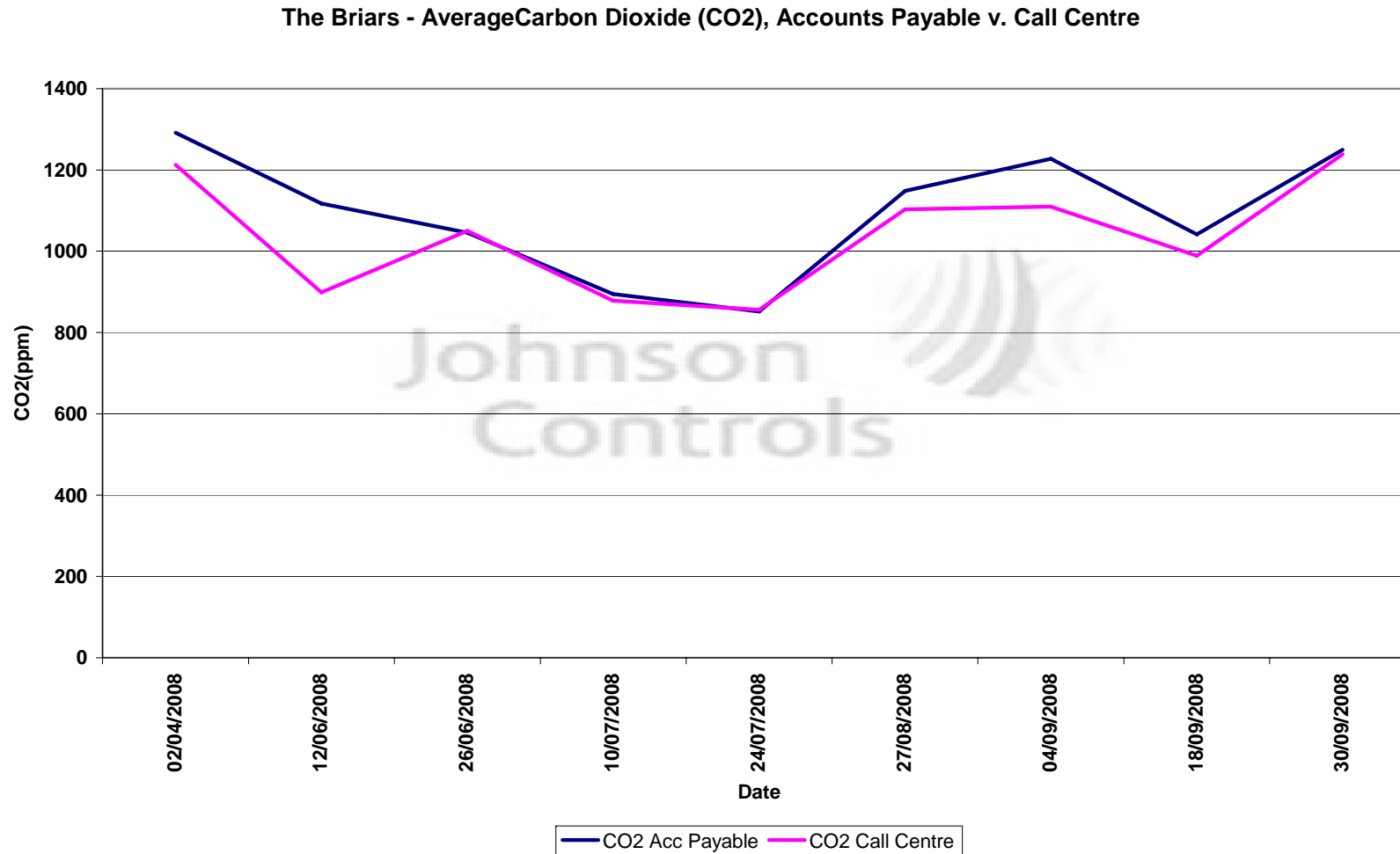


Figure 6: Average Carbon Dioxide Levels, Cannon Street

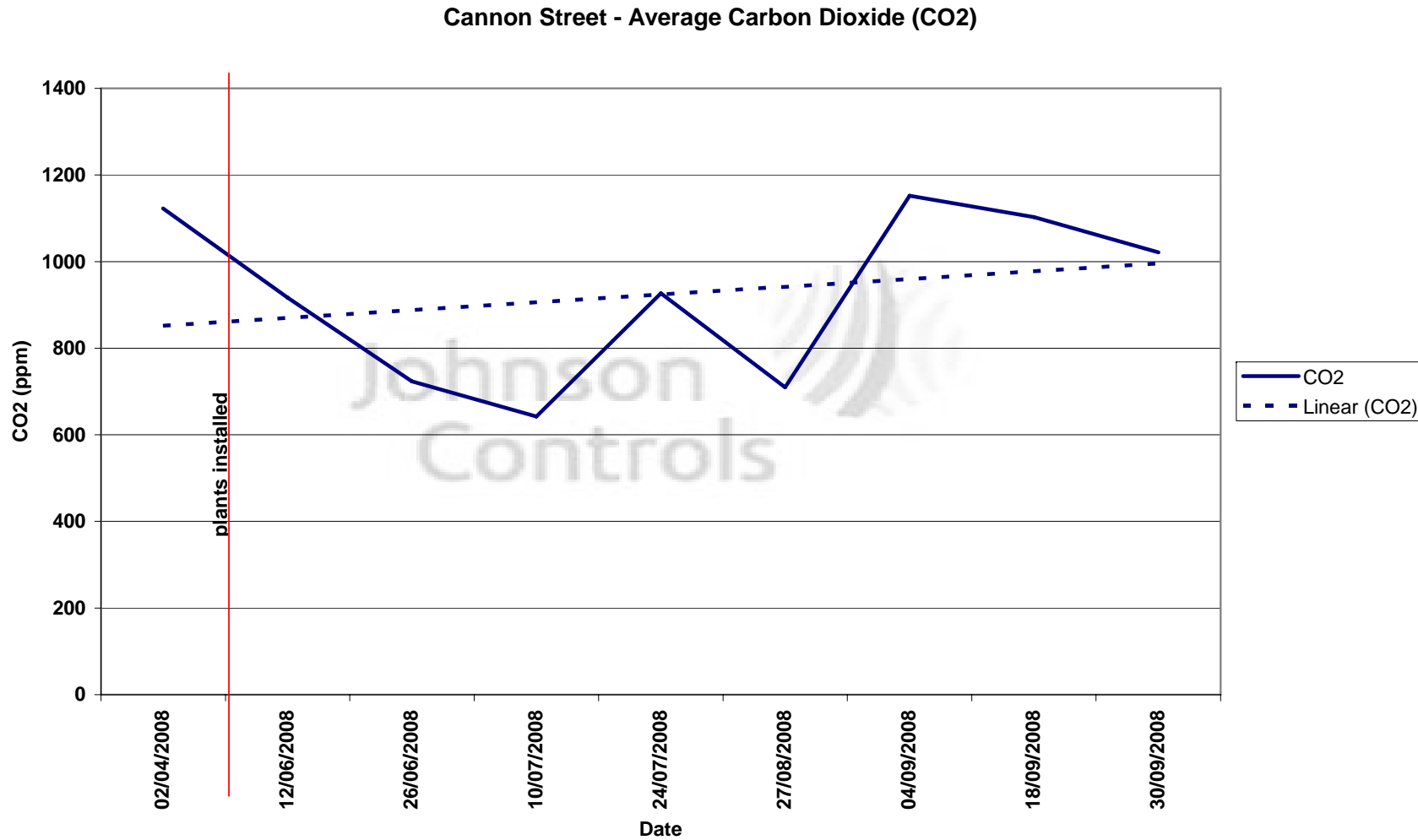


Figure 7: Average Carbon Monoxide Levels, Tower One – 1<sup>st</sup> Floor (without plants) and 2<sup>nd</sup> Floor (with plants)

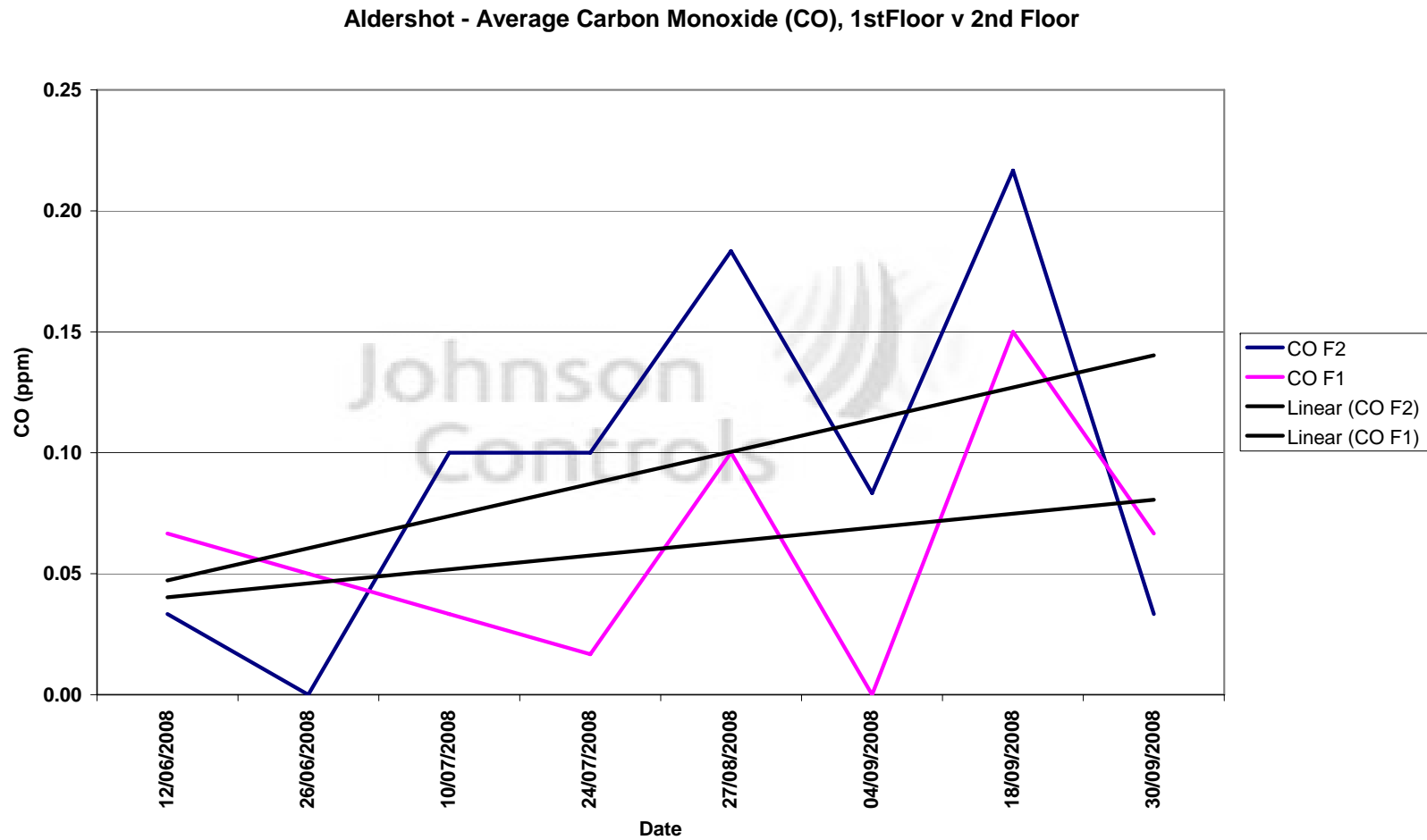


Figure 8: Average Carbon Monoxide Levels, The Briars – Call Centre (without plants) and Accounts Payable (with plants)

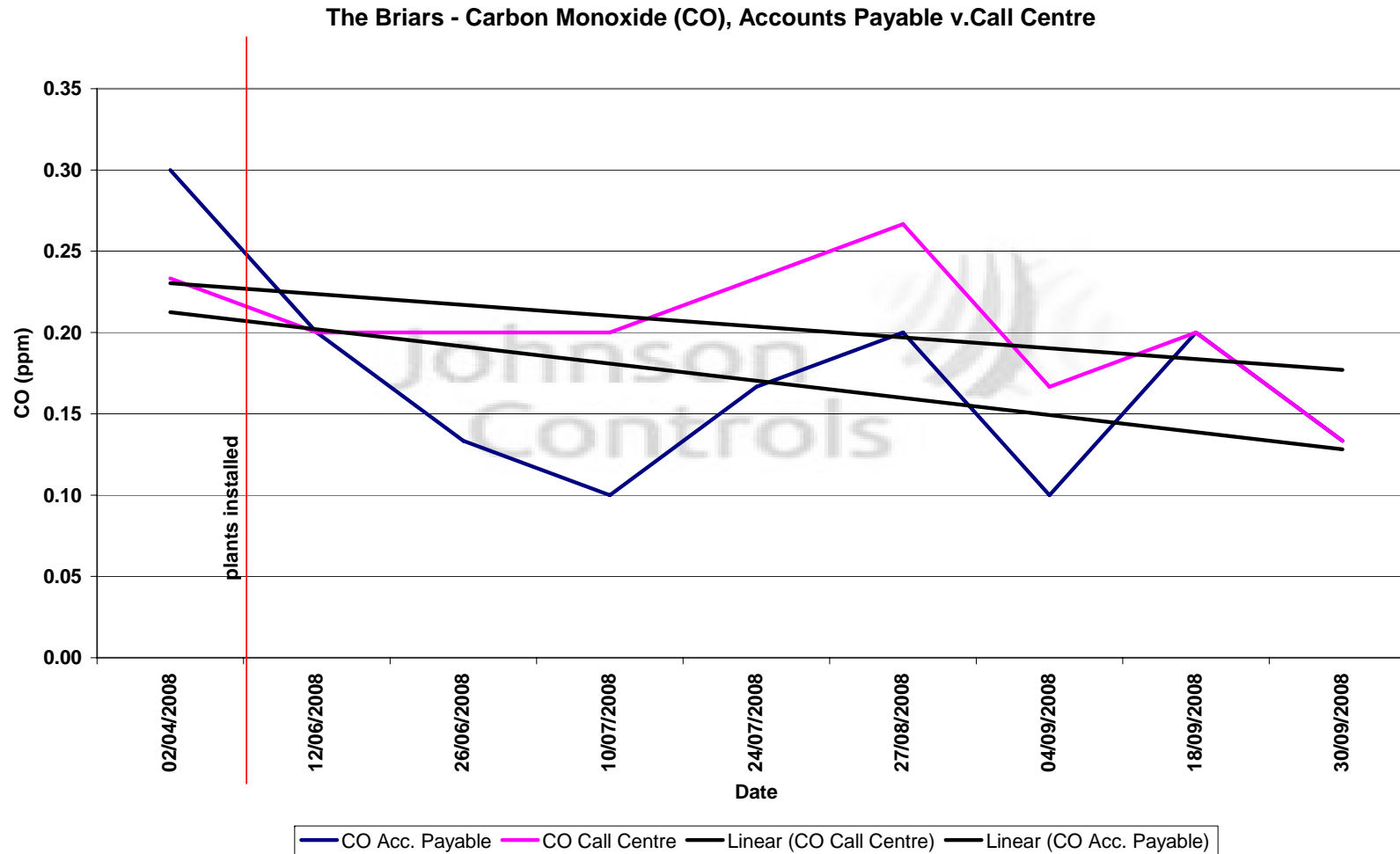
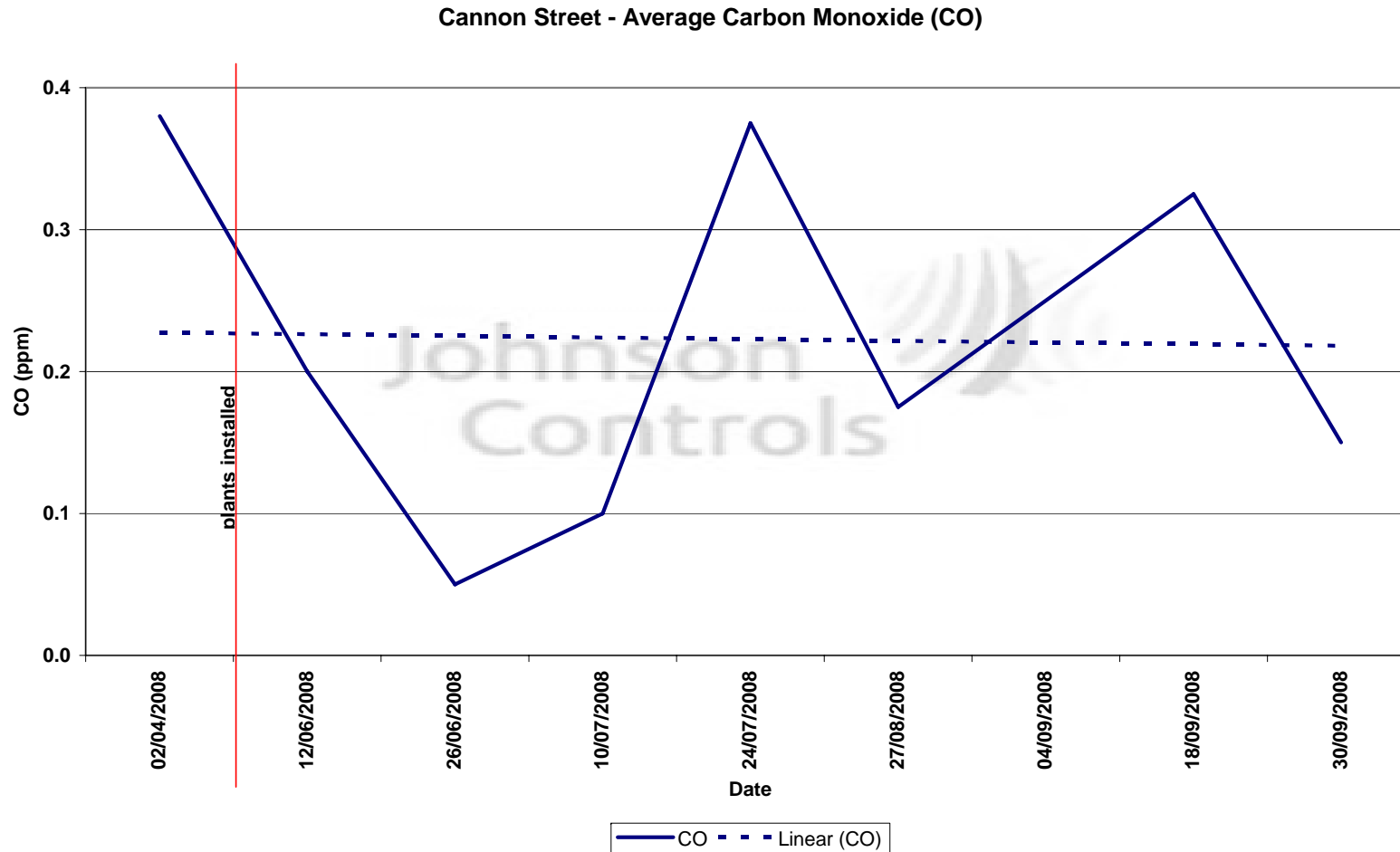


Figure 9: Average Carbon Monoxide Levels, Cannon Street



## Volatile Organic Compounds (VOCs)

Levels of total volatile organic compounds were measured in the three buildings. As plants are known to absorb volatile organic compounds, the expectation was that VOC levels would be lower in the areas with plants compared to the areas without. This was not found to be the case, as levels were consistently lower on the first floor at Aldershot and in the area without plants in the call centre at the Briars. However, this test was limited by the monitoring equipment, which required to be plugged in to a mains socket. Therefore, it may be that the locations of some tests were closer to an emitter of VOCs than others.

Figures 9 to 11 show the VOC data for Cannon Street, Tower One and The Briars.

At Cannon Street, there has been a steady reduction in VOC levels since the plants were installed. A further analysis of the data for Aldershot does show a significant reduction in VOC levels on the second floor, where the plants are installed, as shown in figure 10. However, it shows a similar reduction on the first floor, where there are no plants. The data for the Briars is similar, shown in figure 11. Again, there is a significant reduction since the plants were installed, although the total VOC figures are slightly lower in the area of the office without plants. In the case of the Briars, it is also possible that the plants in one area were affecting the air quality in the other section due to the open plan nature of the office.

This data provides some support for the theory that plants reduce VOC levels. However, it does not explain the slightly lower figures obtained for the areas without plants.



Figure 10: VOC levels, Cannon Street

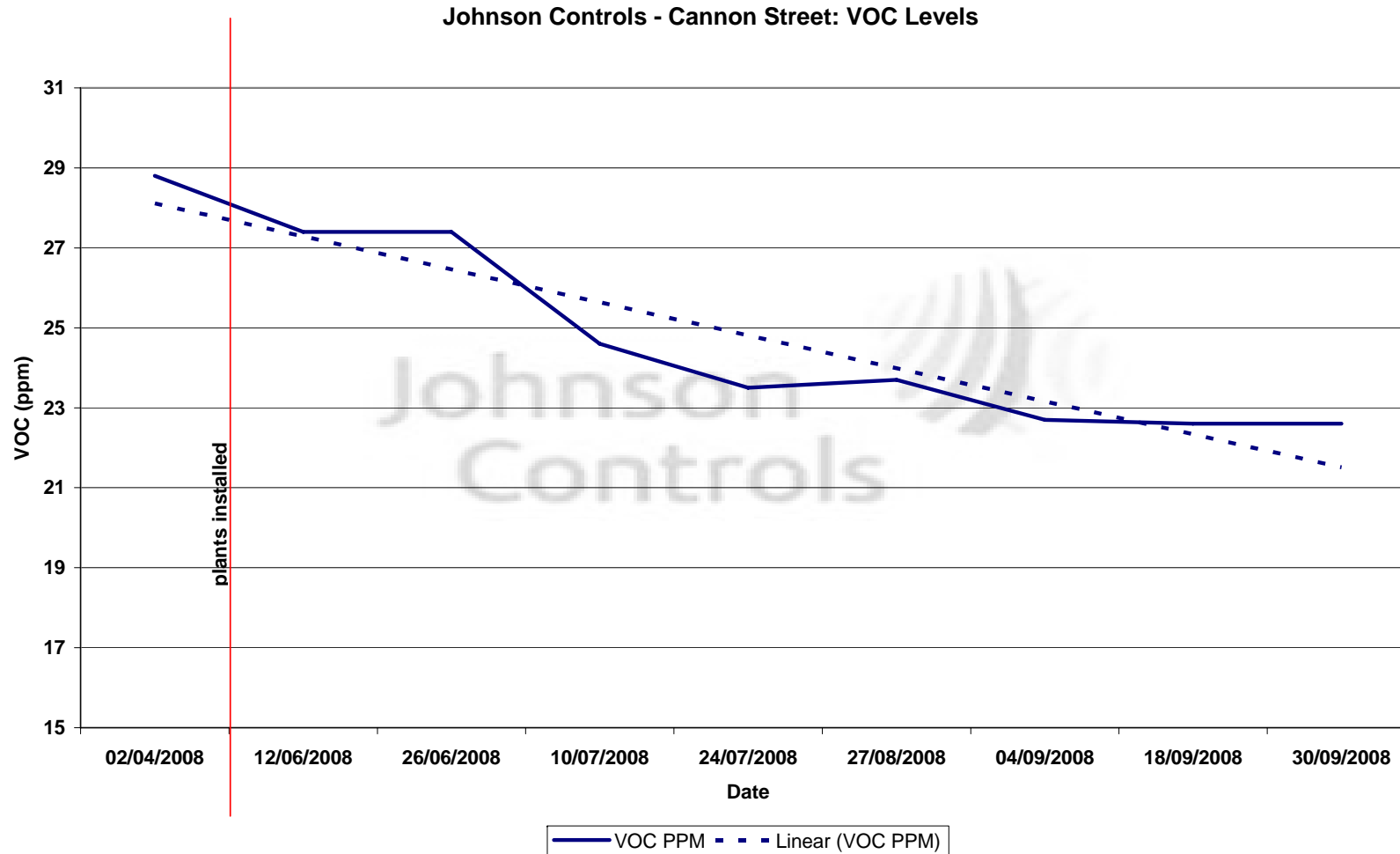


Figure 11: VOC levels, Tower One, Aldershot

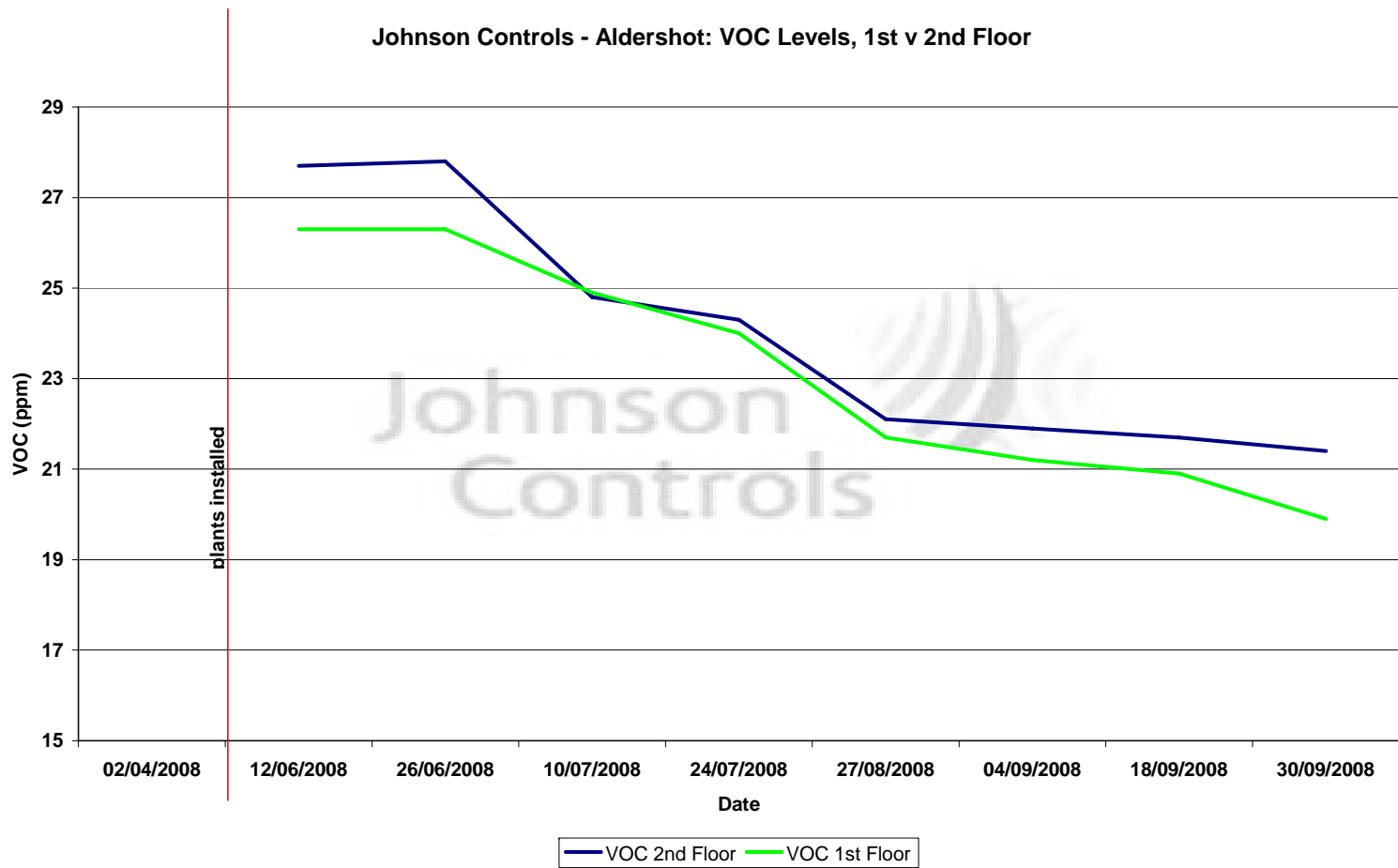
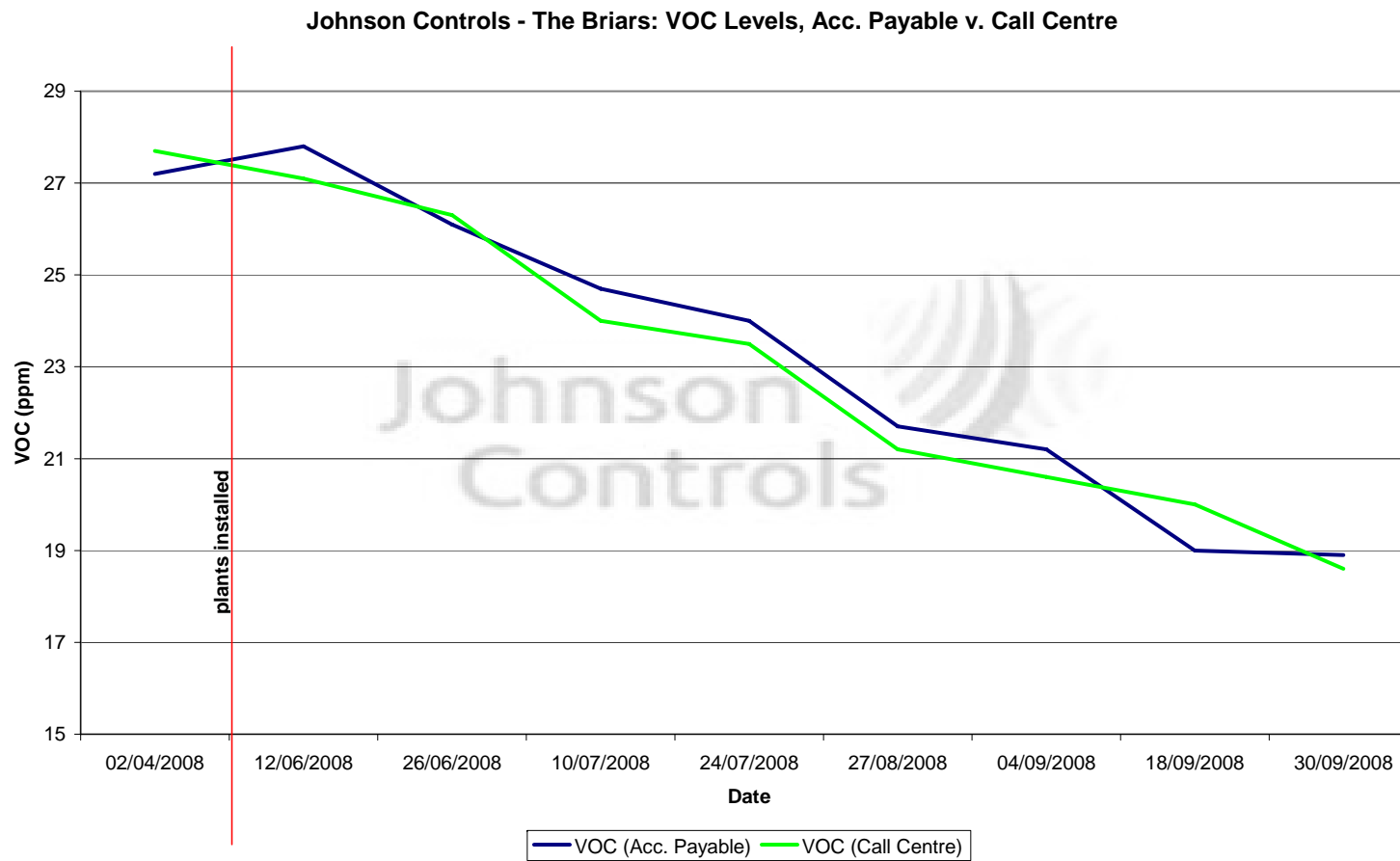


Figure 12: VOC Levels, The Briars, Waterlooville



## User Perceptions

User perceptions were tested using an online survey questionnaire relating to various aspects of the office environment. The first survey was completed during the period before the plants were installed and the survey was completed again after the plants were installed. One change to the survey for the second pass was the addition of a question inviting respondents to add any further comments.

### Survey 1

The first survey was returned by 20 respondents, a relatively low response rate. Of these respondents, 8 (40%) were located at The Briars and 12 (60%) at Park West One in Farnborough. No responses were received from Cannon Street in the first survey. 90% of the respondents indicated they were fixed to one location while the remaining 10% indicated that they are mobile workers.

The first two questions were around whether respondents found the workplace comfortable and whether or not it was well laid out for the work they do. On the question relating to workplace comfort, the majority (75%) agreed or strongly agreed that the workplace was comfortable with only 10% disagreeing. The remaining 15% chose “neutral.” The majority also felt that the workplace was well designed and laid out, with 65% agreeing or strongly agreeing with the statement and 25% disagreeing or strongly disagreeing.

The next statement was regarding whether or not respondents feel productive in their role. 95% of respondents agreed or strongly agreed that they felt productive and 5% disagreed with the statement.

On the statements regarding pressure at work, 40% of respondents agreed that they regularly feel under pressure at work while 50% were neutral and 10% disagreed. Interestingly, it appears that the work environment was generally not perceived to be a contributory factor to pressure felt due to their work. Those disagreeing or strongly disagreeing made up 50% of the respondents, while the remaining 50% were neutral.

On the question as to whether respondents were concerned about their health at work, concerns did not appear to be great, with 15% agreeing with the statement compared to 75% disagreeing and 10% answering “neutral.”

The next two statements considered morale and motivation. On the statement “morale is low in my work area”, 15% agreed that morale was low with 70% disagreeing or strongly disagreeing, indicating that morale is perceived to be relatively high.

Motivation was less convincing with 40% agreeing or strongly agreeing that they are highly motivated to come to work and 10% disagreeing, while the remaining 50% were neutral.

The next four statements considered privacy and communication, which tend to be two of the major complaint areas in open plan offices. The statement relating to personal privacy followed the expected pattern. Those agreeing that privacy was sufficient were 15% with 60% disagreeing or strongly disagreeing and 25% neutral.

However, it appears that the office areas were perceived to enhance communication as 55% agreed or strongly agreed. This is compared to 30% neutral and 15% disagreeing or strongly disagreeing. The noise level in the office was found to be distracting by 45% of respondents while 20% disagreed or strongly disagreed that it was distracting. This may also be due to the locations of the respondents as it may be that one of the locations is physically noisier than the other.

The majority of participants on both did not find it easy to have a private conversation in their work area with 65% disagreeing or strongly disagreeing compared to 15% agreeing with the statement.

Regarding whether or not the office environment helps respondents feel creative, 50% selected neutral, which may be an indication that they did not feel that being creative was a requirement of their role. None of the respondents strongly agreed with this statement and only 5% agreed while 45% disagreed or strongly disagreed.

Again, the respondents did not find the office particularly aesthetically pleasing with 15% agreeing that it was, compared to 40% disagreeing and 45% neutral. These results may also be influenced to some extent by the location of the participants.

It is possible that the presence of plants can lead building occupants to perceive that the temperature is higher than it is, which is useful in cooler environments. The results for temperature were inconclusive, as is common due to the subjective nature of the issue. On the statement regarding whether the temperature is too low, 35% agreed and 40% disagreed, while 20% agreed that it was too high and 45% disagreed. Although the temperature was relatively constant, it is possible that it was physically different between the buildings and floors so these results may not be entirely due to perceptions. The average temperatures for each floor for the duration of the trials are shown in Appendix 1.

On the statement relating to concerns raised about the workplace being taken seriously 45% agreed that they were while 40% were neutral and 15% disagreed. It is probable that answers to this statement were coloured by specific instances when concerns were raised by the individuals.

The last statement tested whether respondents would like more plants in their workplaces. The majority of respondents indicated that they would like more plants with 40% agreeing and 45% strongly agreeing that it would be nice to have more plants. Only one respondent strongly disagreed and 2 respondents were neutral.

Following the installation of plants in the subject buildings at Cannon Street, Tower One and The Briars, the survey was completed again with the addition of a comments box to enable respondents to add more detail in their responses if they wished.

## **Survey 2**

The second survey was returned by 29 respondents. Unfortunately no responses were received from the Briars in the second survey, which makes comparison of the results more problematic. Of all the respondents, 8 (27.6%) were located at Cannon Street and 21 (72.4%) were based at Tower One.

In the second survey, there was a more even split between fixed and mobile workers who responded to the survey. Those indicating they were fixed to one location were 73.1% while 26.9% indicated they were mobile.

The second survey provided a similar pattern of results to the first one, firstly with the results on comfort and workplace design. It is interesting to note that on the results for comfort, a greater percentage of respondents to survey 2 strongly agreed with the statement that the work environment is comfortable, increasing from 5% in the first survey to 27.6% in survey 2. Those strongly agreeing that the work area is well designed and laid out also increased from 5% in survey 1 to 20.7% in survey 2, although the total percentage agreeing or strongly agreeing was similar across both surveys. Those disagreeing with the statements also decreased from 10% to 6.9% for comfort and from 20% to 3.4% for workplace design. This indicates that the presence of the plants may have affected occupants' perceptions of workplace comfort and design.

There was a change in the results relating to pressure at work. There was a drop in those agreeing that they regularly feel under pressure at work from 40% in the first survey to 27.6% in survey 2. However, there was a slight increase in those strongly agreeing from 0% to 6.9%. There was also an increase in those strongly disagreeing from 0% in survey 1 to 6.9% in survey 2. While this may be due to other factors, it is an indication that the presence of plants may lead to reduced perceptions of pressure. Interestingly, however, there was an increase in those who felt that the work environment contributes to pressure felt from 0% agreeing or strongly agreeing in survey 1 to 27.5% in survey 2.

Regarding motivation to come to work, there was an increase in respondents agreeing that they feel highly motivated to come to work from 35% to 44.8%.

Regarding privacy, the scores for having sufficient personal privacy were higher in the second survey than they were in the first. Those agreeing or strongly agreeing that they have sufficient personal privacy increased from 15% in survey 1 to 41.4% in survey 2, while those disagreeing or strongly disagreeing decreased from 60% in survey 1 to 31% in survey 2. This supports the theory that plants increase perceptions of privacy. The results for the office area enhancing communication, noise levels and the ability to have a private conversation were not significantly different.

In a change from the first survey, the second one found greater support for the work environment stimulating creativity. Those respondents agreeing or strongly agreeing that the work environment helps them feel creative increased from 5% to 24.1%, while there was a decrease in those disagreeing or strongly disagreeing from 45% to 31%. This lends support to the theory that offices with living plants are perceived to be more creative.

In the second survey, the offices were also reported as being more aesthetically pleasing than in the first survey. Those agreeing or strongly agreeing increased from 15% in survey 1 to 72.4% in survey 2.

Regarding whether complaints about the workplace are taken seriously, there was a slight increase in those agreeing or strongly agreeing from 45% in survey 1 to 58.6% in the second survey. This suggests that plants may have been perceived to be a workplace improvement measure.

There was a reduction in those agreeing or strongly agreeing that it would be nice to have more office plants from 85% in survey 1 to 75.8% in survey 2, although this shows that the majority would still prefer more office plants. This lends support to the previous research that found a general preference for plants in offices.

The full results of the surveys are shown in table 2.

### Comparison of Farnborough and Aldershot results for surveys 1 and 2

It is also useful to compare the results of survey 1 against those of survey 2 for the respondents who moved from an environment with no plants at Park West One, Farnborough into Tower One at Aldershot, with indoor plants and external views of a natural environment (forest). The statements with significantly different results from survey 1 to survey 2 are discussed below.

On the first statement, relating to whether the work environment was comfortable, the percentage of those agreeing or strongly agreeing increased from 58.3% in survey 1 to 81% in survey 2, while those disagreeing or strongly disagreeing dropped from 16.7% to 4.8%. This is an indication that the planted office with views of nature was perceived to be more comfortable.

In the second survey, the percentage of respondents disagreeing or strongly disagreeing that the work area is well designed and laid out decreased to 0% in survey 2 compared to 41.6% in survey 1. The percentage of those agreeing or strongly agreeing also increased from 41.7% in survey 1 to 76.2% in survey 2. Again, this may suggest an increase in satisfaction with the physical workplace due to the presence of plants and a natural environment setting. However, as the office layout at Aldershot is slightly different to that of Farnborough, this may also have some bearing on this result.

There was a slight decrease in those reporting regular feelings of pressure at work from 58.3% agreeing or strongly agreeing in the first survey to 38.1% in survey 2. There was also an increase in those disagreeing or strongly disagreeing from 8.3% in survey 1 to 14.3% in survey 2. This suggests that those working in the environment with plants and natural environment views felt less stress than those in the environment without plants.

However, those respondents feeling that the work environment contributed to pressure felt due to work increased from 0% agreeing or strongly agreeing in survey 1

compared to 23.8% in survey 2. However, there was also an increase in those disagreeing or strongly disagreeing with 41.6% in survey 1 and 52.4% in survey 2.

There was little change in the results relating to concerns about health at work and morale. Motivation to come to work appeared to be slightly lower in the second survey. Those agreeing or strongly agreeing that they felt motivated decreased from 58.3% to 42.9%, while those disagreeing or strongly disagreeing increased from 0% to 14.3%.

On the statements relating to privacy, perceived privacy did increase following the move to the landscaped office at Aldershot with 0% agreeing or strongly agreeing that they had sufficient personal privacy in survey 1 compared to 33.3% in survey 2. Those disagreeing or strongly disagreeing fell from 83.5% to 38%.

The results regarding the office area enhancing communication were not significantly different although there appeared to be a slight decrease. Those agreeing or strongly agreeing decreased from 58.5% to 47.6%, while those disagreeing or strongly disagreeing increased from 16.6% to 23.8%.

Results on the noise level and the ability to have a personal conversation were similar for the two surveys, suggesting that the plants did not have a significant effect on perceived noise levels causing a distraction. It is probable that a greater number of plants, coupled with strategic placement and greater size of plants would be required to affect this.

There was an increase in perceived creativity from 8.3% agreeing or strongly agreeing in survey 1 to 23.8% in survey 2 and a decrease in those disagreeing or strongly disagreeing from 58.3% down to 28.5%. This indicates that the office with plants and views of a natural environment was perceived to be more creative.

There was a significant increase in the score for the office being aesthetically pleasing with 16.7% agreeing or strongly agreeing in survey 1 compared to 76.2% in survey 2. Those disagreeing decreased from 50% to 4.8%. This result is perhaps not surprising.

There was also a slight increase in those agreeing or strongly agreeing that it would be nice to have more office plants, from 83.3% in the first survey to 90.5% in the second survey. This is a further indication of the general preference for plants in offices.

## General comments

In addition to the ranking of statements, respondents were also given the opportunity to add any other comments at the end of the second survey.

Several comments were received about the plants, which were generally positive, for example comments that it brightens up the office, adds colour makes it look nicer and improves air quality. The negative comments were that one respondent thought they were making them sneeze, while the other negative comments related to the plants only being in certain areas of the office.



Other comments related mainly to issues about temperature, privacy, furniture and noise.

Table 2: Occupant perception survey results

Statement	Strongly Disagree				Disagree				Neutral				Agree				Strongly Agree			
	Survey 1		Survey 2		Survey 1		Survey 2		Survey 1		Survey 2		Survey 1		Survey 2		Survey 1		Survey 2	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
The work environment is comfortable	0	0	0	0	2	10	2	6.9	3	15	6	20.7	14	70	13	44.8	1	5	8	27.6
My work area is well designed & laid out for the job I do	1	5	0	0	4	20	1	3.4	2	10	7	24.1	12	60	15	51.7	1	5	6	20.7
I feel productive in my role	0	0	1	3.4	1	5	2	6.9	0	0	7	24.1	13	65	12	41.4	6	30	7	24.1
I regularly feel under pressure at work	0	0	2	6.9	2	10	2	6.9	10	50	15	51.7	8	40	8	27.6	0	0	2	6.9
My work environment contributes to pressure I feel due to my work	1	5	2	6.9	9	45	13	44.8	10	50	6	20.7	0	0	7	24.1	0	0	1	3.4
I am concerned about my health at work	4	20	8	27.6	11	55	9	31	2	10	6	20.7	3	15	4	13.8	0	0	2	6.9
Morale is low in my work area	3	15	7	24.1	11	55	11	37.9	3	15	5	17.2	3	15	6	20.7	0	0	0	0
I feel highly motivated to come to work	0	0	2	6.9	2	10	2	6.9	10	50	11	37.9	7	35	13	44.8	1	5	1	3.4
I have sufficient personal privacy in my work area	3	15	4	13.8	9	45	5	17.2	5	25	8	27.6	3	15	10	34.5	0	0	2	6.9
My office area enhances communication	1	5	4	13.8	2	10	3	10.3	6	30	6	20.7	9	45	14	48.3	2	10	2	6.9
The noise level in my office is distracting	1	5	3	10.3	3	15	2	6.9	7	35	8	27.6	8	40	9	31	1	5	7	24.1
I can easily have a private conversation in my work area	7	35	7	24.1	6	30	12	41.4	4	20	6	20.7	3	15	3	10.3	0	0	1	3.4
The work environment helps me feel creative	1	5	2	6.9	8	40	7	24.1	10	50	13	44.8	1	5	6	20.7	0	0	1	3.4
The office design is aesthetically pleasing	1	5	1	3.4	7	35	1	3.4	9	45	6	20.7	3	15	16	55.2	0	0	5	17.2
The temperature in the office is too low	0	0	0	0	8	40	11	37.9	5	25	9	31	7	35	5	17.2	0	0	4	13.8
The temperature in the office is too high	1	5	3	10.3	8	40	14	48.3	7	35	10	34.5	4	20	2	6.9	0	0	0	0
Any concerns I have raised about the workplace are taken seriously	0	0	4	13.8	3	15	2	6.9	8	40	6	20.7	9	45	13	44.8	0	0	4	13.8
It would be nice to have more office plants	1	5	0	0	0	0	2	6.9	2	10	5	17.2	8	40	13	44.8	9	45	9	31

## Conclusions

This report presents the findings of a six month trial of interior plants conducted by Liverpool John Moores University and GP Plantscape at Johnson Controls at Cannon Street, Tower One and The Briars. The benefits of plants were tested using a combination of air quality monitoring equipment and staff perception surveys to determine the benefits of plants to physical air quality and psychological factors.

Previous studies have uncovered evidence of the ability of plants to balance indoor relative humidity, remove carbon dioxide and other gases such as carbon monoxide, remove volatile organic compounds, which have been linked to cancer and to remove airborne particles such as dust and printer emissions.

Evidence is also available regarding the psychological benefits of plants. Indoor plants have been shown to reduce stress levels, affect mood and perceived health and also improve productivity.

Prior to the trials commencing, air quality assessments were completed at Cannon Street and The Briars and relative humidity was found to be around 38 - 40%, which required action due to the increased risk of health disorders such as asthma and eczema being caused by dry indoor air. The recommended level for indoor humidity is in the range of 40 – 70%. Carbon monoxide was found to be well within recommended levels and carbon dioxide was slightly above the recommended maximum of 1000 ppm.

Plants were provided by GP Plantscape and installed for 6 months for the trials. The plants were installed in Cannon Street, the second floor at Tower One and the Accounts Payable area at The Briars. Indoor air quality readings were taken on a regular basis and two staff surveys were issued during this time.

Humidity was found to be slightly higher on the floor with plants at Aldershot. At The Briars, an upward trend was noted following the installation of the plants and the readings for the two areas studied were close. It is possible that the same air was circulated around both areas due to the open plan nature of the building. A linear increase in relative humidity to within recommended levels was also noted at Cannon Street. This provides support for the theory that plants raise the humidity level within offices.

Contrary to expectations, carbon dioxide levels were slightly higher on the floor with plants at Tower One, with the results at The Briars following the same pattern. At Cannon Street, the carbon dioxide unexpectedly increased slightly over the trial period. This does not support the theory that plants reduce the level of carbon dioxide. However, this is not in line with the findings of other studies and this result is currently unexplained. Further research would be required to establish the reasons for this.

Carbon monoxide increased slightly at Tower One but followed the expected pattern by reducing at The Briars and Cannon Street. This data suggests that the plants had a beneficial effect on the carbon monoxide levels.

Volatile organic compound levels reduced over the period of the trials at all three locations. However, in some cases, the total volatile organic compound level was lower in the areas without plants. This test was limited by the equipment, however, as it required to be plugged in to a mains socket and did not fit all the sockets in the trial locations. It is possible, therefore, that some readings may have been taken closer to a VOC emission source than other. The data does suggest, however, that the VOC level was reduced as a result of the plants.

User perceptions of the workplace were examined using online surveys. In the office with plants and a view of natural surroundings, respondents found their office more comfortable, better designed and laid out and felt slightly less pressure than they did in the office without plants. They also perceived that privacy levels had increased as well as perceptions that the work environment made them feel creative. They also felt that the office with plants was more aesthetically pleasing than the one without plants. However, there was an increase in feelings that the work environment contributed to pressure felt due to work. Motivation was also reported as being slightly lower in the second survey, following the installation of the plants.

The majority of respondents to both surveys indicated that they would like more plants in their offices. This supports the general preference for offices with plants compared to offices without plants identified previously.

The results relating to temperature were inconclusive for both surveys. This reflects the subjective nature of temperature within offices. What one individual finds comfortable, others may feel is too cold or too warm.

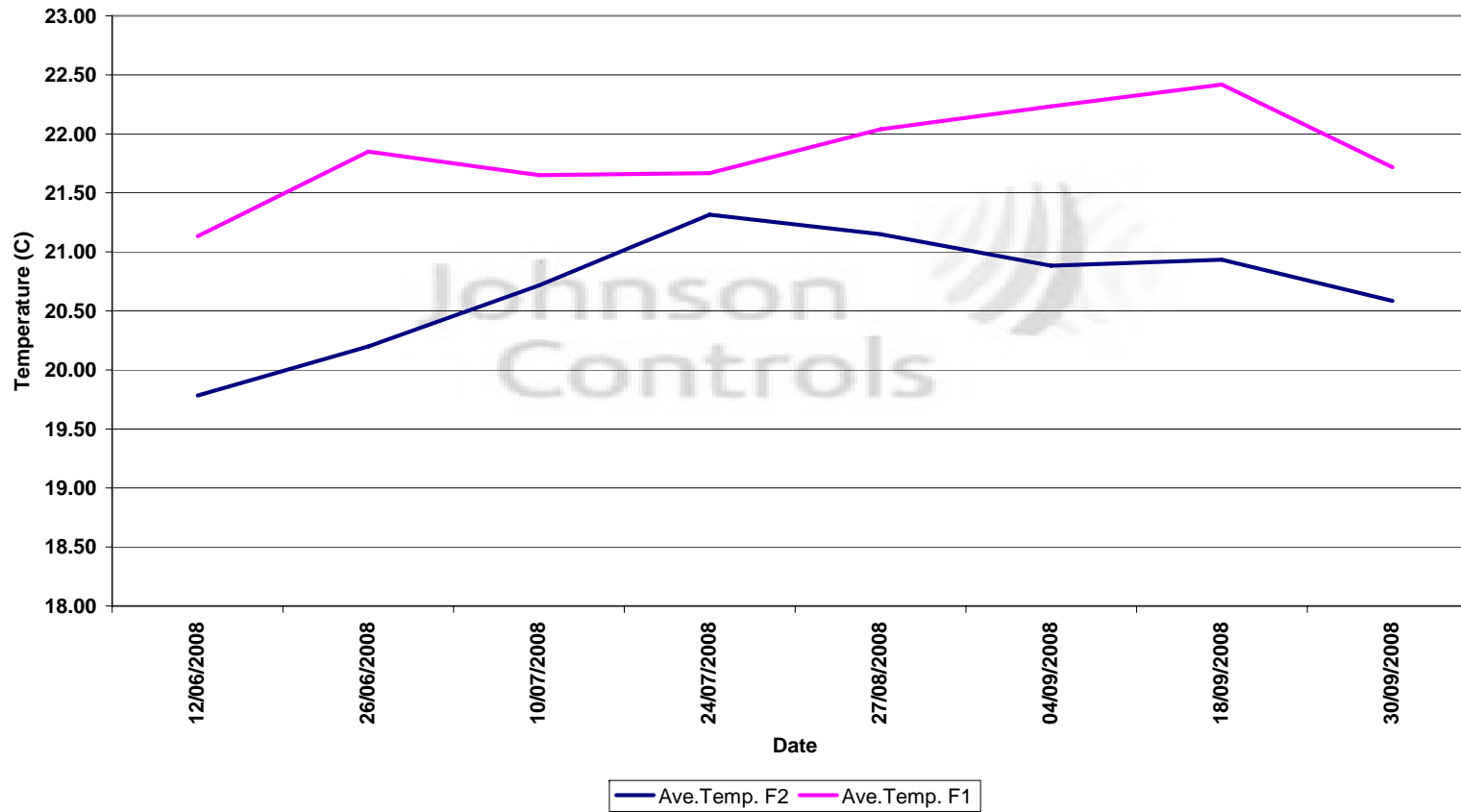
These results, in general, provide support for the theories that plants benefit indoor air quality and provide psychological benefits to office occupants. The results may be due to a range of factors, but they provide an indication of the benefits of plants to the working environment.

## **Recommendation**

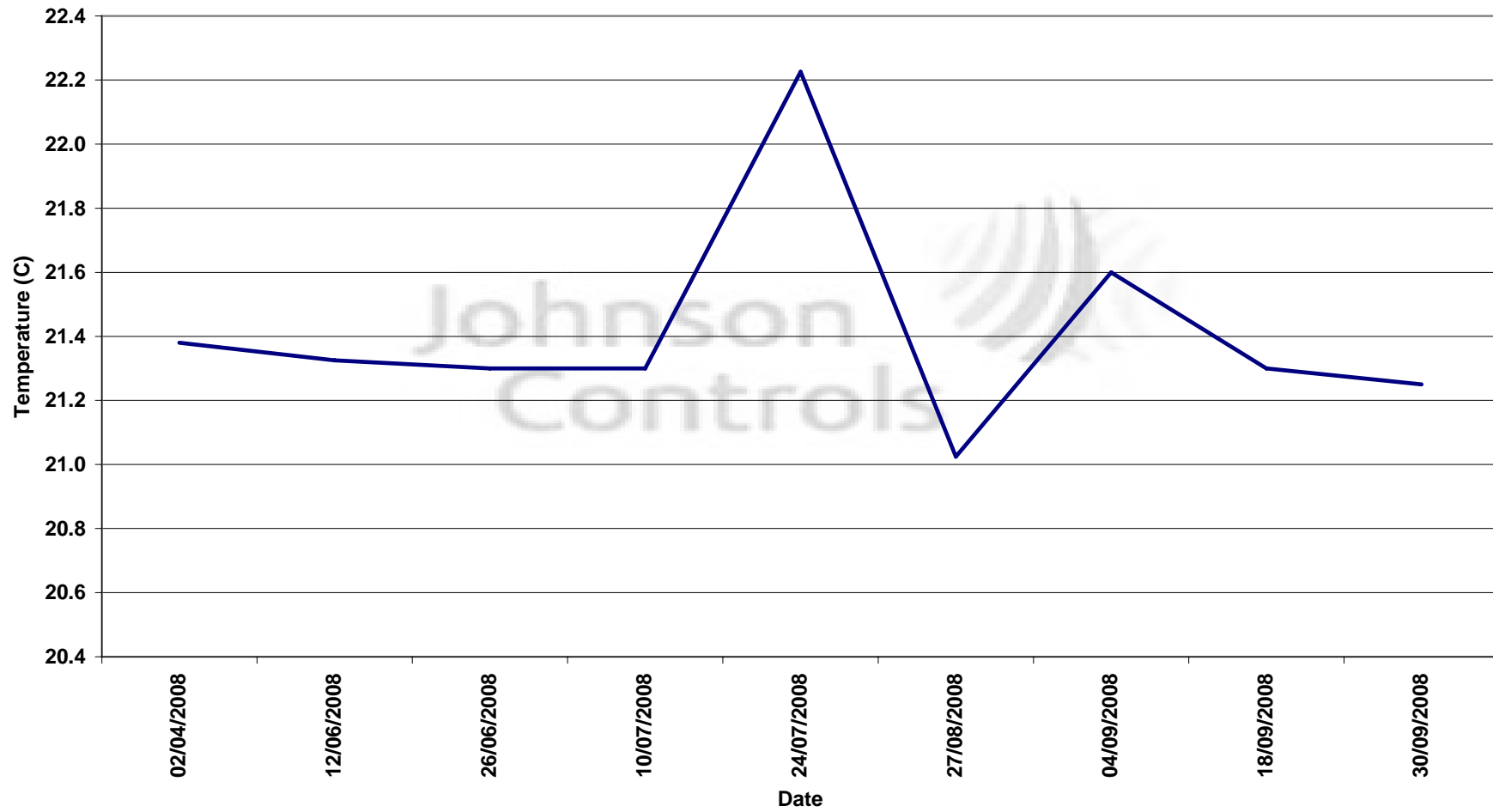
The results of the tests and surveys carried out may be due to several factors. However, they provide an indication that plants are likely to bring both air quality and psychological benefits to the working environment, making it beneficial to install living plants in all office areas.

# Appendix 1 – Average Temperatures

Aldershot: Average Temperature, 1st Floor v. 2nd Floor - June - September 2008



Cannon Street: Average Temperature - April - September 2008



The Briars: Average Temperature, Call Centre v. Accounts Payable - April - September 2008

