SYDNEY POSTHARVEST LABORATORY

Postal Address: PO Box 62, North Ryde, NSW 1670, AUSTRALIA
Street Address: CSIRO Food Science Australia Building, 11 Julius Avenue,
Riverside Corporate Park, North Ryde, NSW 2113, AUSTRALIA

Evaluation of Aircode TA/TG-400, ID-500 and CX-600 Ion Generating Units for Power Tower Cloud / Airgan

SUMMARY

Negative ions generated the by CX-600 and Aircode TA/TG-400 units reduced levels of a range of air-borne pollutants, including:

- ***Microorganisms***
  - reduction of bacteria levels suspended in the air in a working environment at West Pennant Hills Sports Club by **49%** and at Star City Casino by **52%**
  - reduction of mould levels suspended in the air in a working environment at West Pennant Hills Sports Club by 23% and at Star City Casino by 9%
  - reduced viability of *B. cinerea* spores on metal surface by **56%**.
  - reduced viability of high levels of *P. expansum* spores on metal surface by up to **95%**
- ***Odours***
  - 5% removal of butyric acid (vomit smell) in test chamber
  - reduction of smoke and other odours by **59%** in a working environment at West Pennant Hills Sports Club under low to moderate levels of cigarette smoke (no odours and smoke was detected at Star City Casino)
  - up to 20 times faster reduction of cigarette smoke compounds (odours) under very high levels of cigarette smoke in test room and 17% faster reduction in test chamber
  - no significant effect on ammonia levels in test chamber
- ***Air-borne particulates***
  - reduction of dust and particles in the air in a working environment at West Pennant Hills Sports Club by **49%** (up to **69%** reduction in the poorest quality air) and at Star City Casino by **45%**
  - up to **13%** reduction of dust particles in test chamber and **19%** in the test room, ionisation quickly reduces larger size particles in **the first few minutes**.
- ***Ethylen***e
  - at the higher expected levels of ethylene in cool rooms of several ppm, the CX-600 ionisation unit reduced ethylene from 3 ppm to almost zero (0.1 ppm) over several hours. The decline in ethylene due to the CX-600 unit was almost 15 times more rapid than without the CX-600 unit.

BACKGROUND

The CX-600, ID-500 and Aircode TA/TG-400 ionisation units generate negative ions, which can cause fine air particles (*eg*. dust, smoke, microbial spores etc) with opposite charges to stick together. Densely combined particulates may eventually precipitate (fall out) of the air, thus creating a cleaner air environment. Air ionisation may also eliminate volatile odours,

ABN 82 249 616 581 Phone: (+61-2)/ (02) 9490-8443 Fax: (+61-2)/ (02) 9490-8499 Mobile: (+61-410)/ (0410) 603-170
Email: spl@postharvest.com.au Web: http://www.postharvest.com.au

particularly if the odour-bearing molecules are attached to particulates suspended in the air.

The aim of these studies was to test efficacy of the CX-600 and Aircode TA/TG-400 ionisation units to eliminate various pollutants and improve air quality. Tests were performed using specialised equipment at the Sydney Postharvest Laboratory.

RESULTS

1. Microbial reduction

A. Tests on Metal Surfaces

The fungi *Botrytis cinerea* and *Penicillium expansum*, both causing common rots on fruits and vegetables, were cultured on Malt Extract Agar (MEA) medium and the bacteria *Escherichia coli*, a common human infection agent occurring in faecal contaminated foods and water, was cultured on Nutrient Agar (NA) medium. Aqueous suspensions of microbial cells/spores isolated from the cultures were applied as 200µl drops on aluminium strips, allowed to dry and exposed to ionised air for 2 and/or 4 hours. The CX-600 ionising unit was used with the fan speed set at ½ and ionisation level at 1, to produce negative ions of 10,000 to 15,000 ions/cm^3 within a room of approximately 30 m^3 volume.

Botrytis cinerea

Ability of ionisation to eliminate *B. cinerea* was low partly due to low initial numbers of spores present (log 2.11 colony forming units [cfu]/cm^2), but it seems that negative ions had some effect on reducing levels of *B. cinerea* (Table 1). For example, viability of Botrytis spores was reduced by 56% after 4 hours ionisation. However, it is possible that a greater % kill rate of spores would occur with a higher initial spore count.

Table 1. Effect of air ionisation on viability of *Botrytis cinerea*

Time	Control (log cfu/cm^2)	Ionisation (log cfu/cm^2)	Log reduction by ionisation	% reduction by ionisation
Initial	2.11	2.11	-	-
2 hours	1.96	2.17	0	0
4 hours	1.83	1.58	0.25	56%

Penicillium expansum

Two separate trials were conducted on the fungus *Penicillium expansum* using the same experimental conditions described for *B. cinerea*. The reduction of *P. expansum* due to ionising particles was significant in the first trial (Test A), where negative ions reduced levels of *P. expansum* after four hours by 95.1% (Table 2). However, in the second trial (Test B), ionisation had no effect in eliminating fungal spores, however, in this test very high levels of spores were used, that would be much higher than would be normally found.

Spores of *P. expansum* were susceptible to air ionisation when spore concentrations are at moderate to high levels, however, benefits of ionisation are not so apparent when spore levels are extremely high. Further, these tests are only for the organism on a metal surface, they do not test what would happen if the bacteria were suspended in the air.

Table 2. Effect of air ionisation on viability of *Penicillium expansum* in Tests A and B

Test A

Time	Control (log cfu/cm^2)	Ionisation (log cfu/cm^2)	Log reduction by ionisation	% log reduction by ionisation
Initial	6.69	6.69	-	-
2 hours	6.47	6.31	0.16	30.8%
4 hours	6.44	5.13	1.31	95.1%

Test B

Time	Control (log cfu/cm^2)	Ionisation (log cfu/cm^2)	Log reduction by ionisation	% log reduction by ionisation
Initial	8.67	8.67	-	-
4 hours	8.85	9.23	-	-

Escherichia coli

Another trial using *Escherichia coli* (which is a common human pathogen or disease causing organism especially the digestive system), showed that generation of negative ions in air had no effect in decreasing viability of *E. coli* cells on the aluminium strip (Table 3). However, it is possible that other isolates of *E. coli* are sensitive to air ionisation. Further, these tests are only for the organism on a metal surface, they do not test what would happen if the bacteria were suspended in the air.

Table 3. Effect of air ionisation on viability of *Escherichia coli*

Time	Control (log cfu/cm^2)	Ionisation (log cfu/cm^2)	Log reduction by ionisation	% log reduction by ionisation
Initial	11.16	11.16	-	-
4 hours	10.52	10.59	-	-

B. Tests of Bacteria and Mould Suspended in Air

Air-borne microorganisms – Star City Casino

Petri dishes containing different media to promote bacterial and mould growth (Nutrient Agar and Malt Extract Agar, respectively) were exposed to the air for various times with and without ionisation in the VIP lounge, Star City Casino.

When all times were averaged, the bacterial levels in the air were reduced on average by more than 50% when the ionization unit was running (Table 4), while the reduction in mould levels was lower at only 9% on average. For more definitive results, further collection of air-borne microorganisms is recommended at longer exposure times, particularly when there is a high load of persons in the area.

Table 4. Reduction in mould and bacteria in the air in the VIP room, Star City Casino.

Time the test plate was exposed (minutes)	No ionization (per plate)	With ionization (per plate)	% reduction due to ionization
Mould			
0.03	0.25	0.25	0%
1:00	0.5	0	100%
3:00	0	0	0%
10:00	0.75	1	-33%
30:00	1.25	1.5	-20%
Average effect on mould			***9% reduction***
Bacteria			
0:03	0.5	0	100%
1:00	1.25	0.25	80%
3:00	0.5	0.5	0%
10:00	1	0.5	50%
30:00	3.25	2.25	31%
Average effect on bacteria			***52% reduction***

Air-borne microorganisms – West Pennant Hills Sports Club
Petri dishes containing Nutrient Agar medium to promote microbial growth were exposed to the air for various times with and without ionisation in the Games Room, West Pennant Hills Sports Club.

When all times were averaged, the bacterial levels in the air were reduced on average by more than 49% when the ionisation unit was running (Table 5), while the reduction in mould levels was lower at only 23% on average. Total reduction of air-borne microorganisms while the ionisation unit was operating was 45%.

These tests of bacteria and mould suspended in air show higher levels of control than on metal surfaces.

Table 5. Reduction in mould and bacteria in the air in the Games Room, West Pennant Hills Sports Club

Time the test plate was exposed (minutes)	No ionisation (per plate)	With ionisation (per plate)	% reduction due to ionisation
Mould			
30 min	1.9	1.6	***16%***
60 min	3.7	2.6	***30%***
Average effect on mould			***23% reduction***
Bacteria			
30 min	9.4	4.3	***54%***
60 min	18.0	10.1	***44%***
Average effect on bacteria			***49% reduction***
All microorganisms			
30 min	11.3	5.9	***48%***
60 min	21.7	12.7	***42%***
Average effect on microorganisms			***45% reduction***

2. Odour Reduction

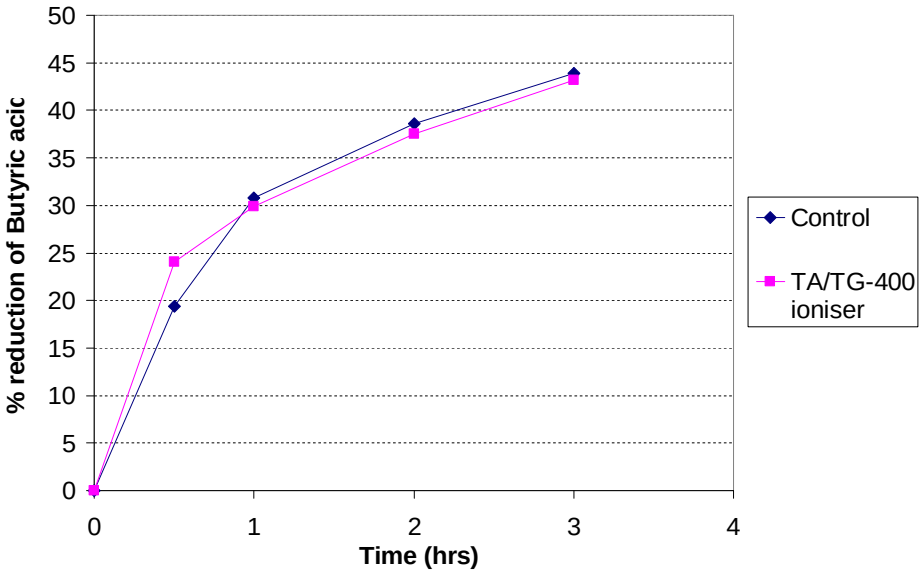
Use of air ionisation to reduce unpleasant volatile compounds, including butyric acid (vomit smell), ammonia (associated with composting, body odour, urine) and cigarette (tobacco) smoke, was tested within a closed glass tank (0.21 m^3) using the Aircode™ TA/TG-400 unit. A small portable fan was placed in the tank to assist dispersal of negative ions of approximately 2,000 to 5,000 per cm^3. In addition, the CX-600 unit was tested to remove cigarette smoke compounds, at a fan speed of *ca*. ¼ and ionisation setting of 3, which generated 12,000 to 18,000 ions/cm^3 within a closed room of approximately 30 m^3.

At various intervals, the odours were collected using solid phase microextraction (SPME) techniques or as a direct gas sample for analysis by gas chromatography (GC). Total peak area(s) of volatile compounds (odours) were compared to control treatments without ionisation exposure.

Butyric acid

Ionisation during the first 30 minutes there was an accelerated removal of butyric acid odour (24% loss of butyric acid, compared to 19% loss in the control), resulting in a 20.8% increased removal of butyric acid by ionisation. For longer periods up to 4 hours, there was no further removal of butyric acid with ongoing ionisation. It is probable that some butyric acid molecules were removed from the air due to a precipitation of particulates (*eg*. dust) by ionisation during the early part of the test period.

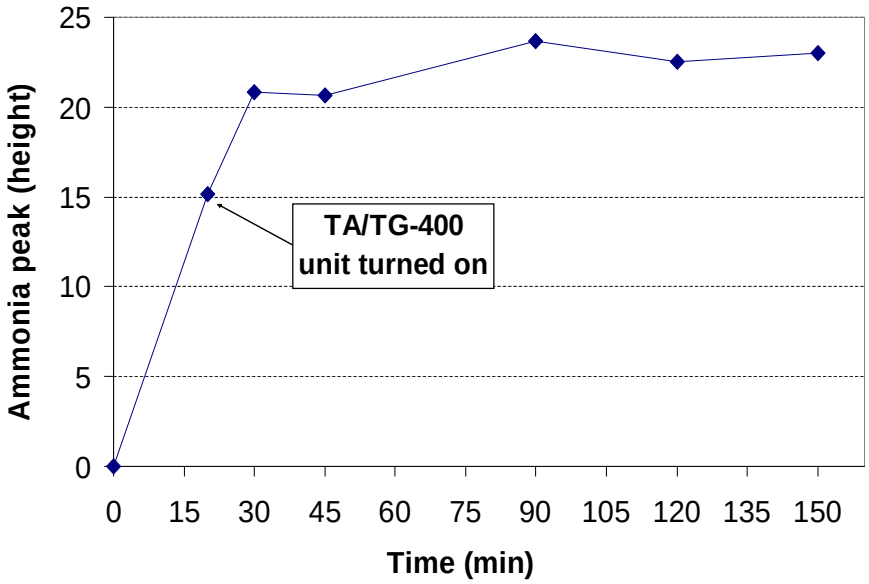
Fig. 1 Reduction of butyric acid odour by air ionisation using the AirCode TA/TG-400 unit. Values are means of 2 replicates



Ammonia

Ammonia has a strong, pungent odour that is easily recognisable in animal (*eg*. cat, rabbit) urine, composts and in the sweat of people. The aim of this study was to determine if TA/TG-600 ionisation unit has capacity to eliminate ammonia odour. Ammonia solution (100ml) dispensed in an open flat container was used to generate ammonia vapour within a closed test chamber (0.21 m^3). After 20min, the solution was removed by suction via a tube, and the Aircode TA/TG-400 unit was turned on. Ammonia was sampled at various intervals for up to 3 hours; however ionisation showed no effect in reducing the level of ammonia gas (Fig. 2).

Fig. 2 Effect of ionisation on ammonia gas using the AirCode TA/TG-400 unit.



Cigarette smoke compounds

Air ionisation by the Aircode TA/TG-400 unit demonstrated a capability to remove volatile cigarette smoke compounds. For example, after 1 hour ionisation there was a 73% drop in the level of smoke compounds, compared with the control which had a 61% decrease in the level of smoke compounds (Fig. 3), which is an additional reduction of 17% of cigarette smoke due to ionisation. This pattern continued at 4 hours, where the extent of reduction in the level of cigarette compounds caused by ionisation (89% decrease) was greater than the control (79% decrease), a reduction of about 13%. The levels of smoke produced in the small test chamber used with the TA/TG-400 were about 10 times higher than those found at the West Pennant Hills Sports Club, so the air ioniser may have been overloaded and better results may have been obtained with lower levels of smoke, similar to those found in bars and clubs.

Fig. 3 Removal of cigarette smoke compounds due to ionisation by the Aircode TA/TG-400 unit. Values are means of 2 replicates.

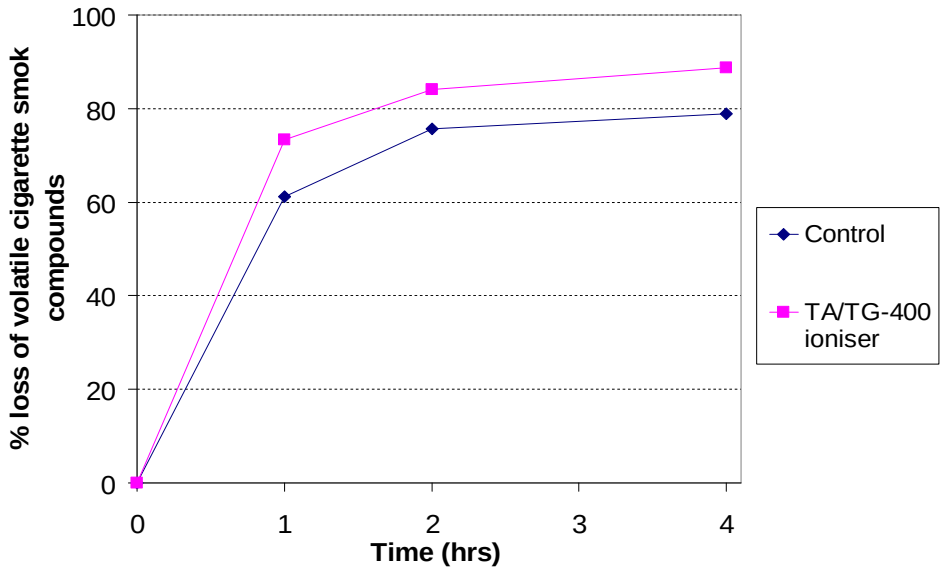
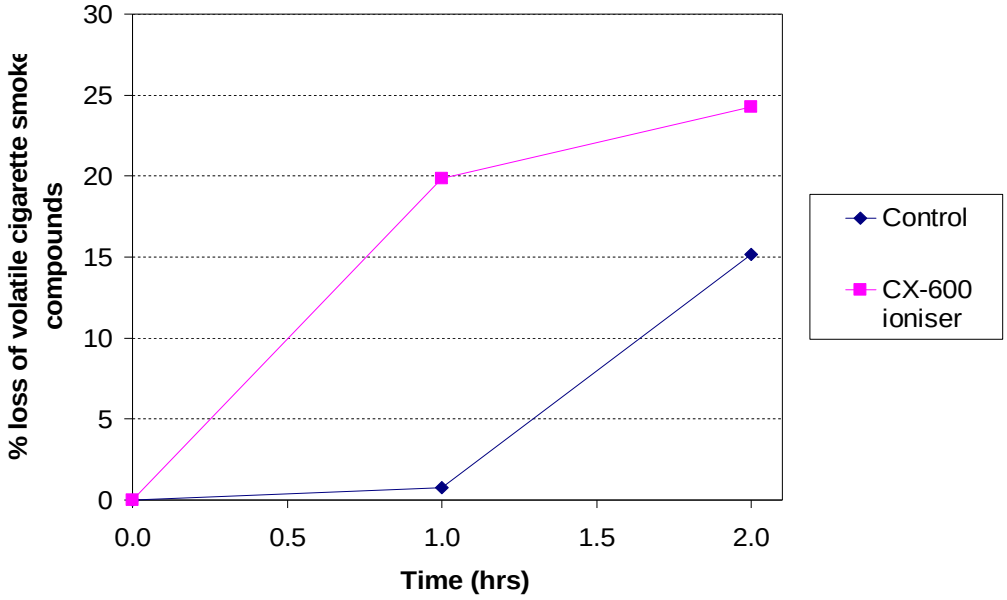
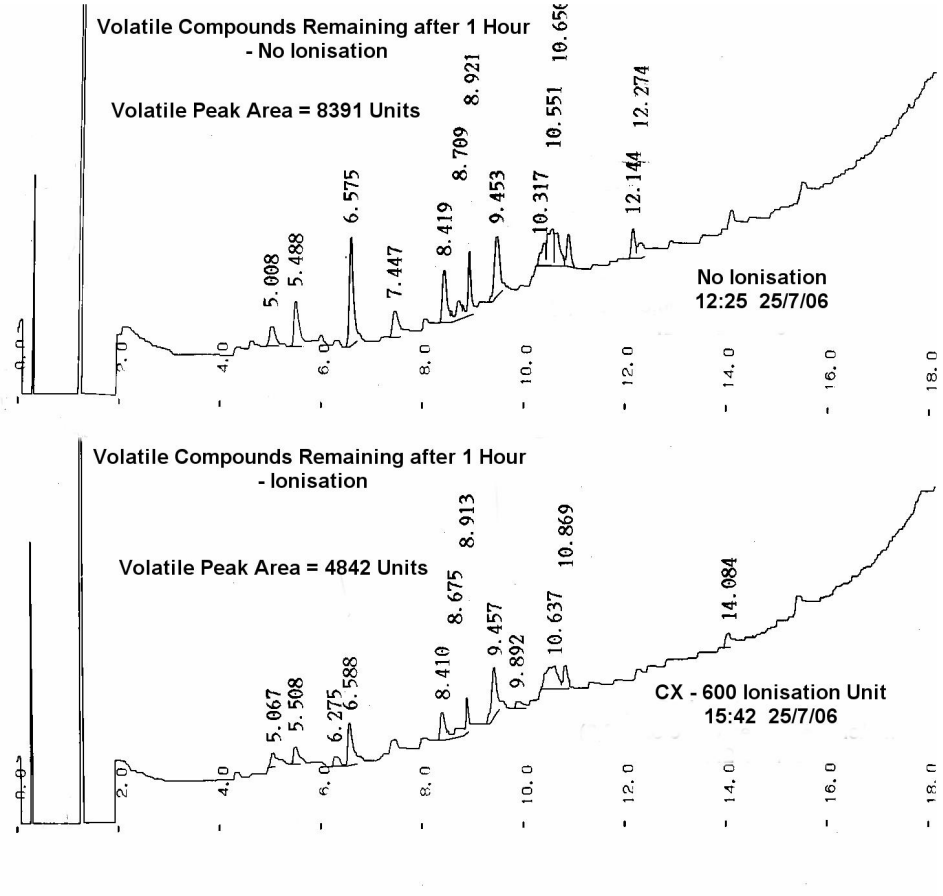


Fig. 4 Effect of ionisation by the CX-600 unit on cigarette smoke compounds.



With trials using the CX-600 unit, ionisation successfully accelerated removal of volatile smoke compounds after 1 hour (20% removal), in relation to the control which showed practically no loss (*ca*. 1%) of smoke compounds, so the increased loss due to ionization was

Figure 5 Chromotagraph of SPME extract of cigarette smoke volatiles after one hour exposure to CX-600 Ioniser or without ionization



20 times greater than that normally expected (Fig. 4). After 2 hours, the level of volatile smoke compounds continued to decrease due to ionisation (24% loss), although the control also showed some loss of smoke compounds (15% loss), in this instance the increases relative loss due to ionization was 37.5%. Longer periods of ionisation at a higher setting of ionizing voltage might further improve elimination of volatile smoke compounds. An example of the cigarette smoke volatiles and the difference after one hour due to the CX-600 is shown in the two chromotagraphs in Figure 5.

Odours – Star City Casino

The unit used in the air ducting at Star City Casino was an ID-500 model (similar to the CX-600 but without a fan). Air at the casino was sampled in 45ml vials, which were exposed to the air for 60 minutes before being sealed. Prior to analysis for odours, the vials were heated to 50C for 15 minutes to ensure that no odours were attached to the sides of the vials. Odours were then concentrated by being absorbed for 30 minutes onto SPME fibres. Samples were then analysed by gas chromatography using a temperature gradient from 40 to 220C and a FID detector.

Average total peak area counts of aromas in the air for eight samples

i. Without ionisation aroma total peak areas = 6220
ii. With ionisation aroma total peak areas = 6555

There is no significant difference in aromas in the air with or without air ionisation. The levels of human, food and smoke odours or aromas in the air were very low and hence do not allow significant differences to be fully tested determined. More definite results would be expected if air samples were taken when the air was recognizably tainted (*eg.* during garbage collection times near air intakes ducts) or when a large number of people were present in the room.

Odours – West Pennant Hills Sports Club

The unit used in the air ducting at West Pennant Hills Sports Club was an ID-500 model (similar to the CX-600 but without a fan). Air at the casino was sampled in 45ml vials, which were exposed to the air for 60 minutes before being sealed. Prior to analysis for odours, the vials were heated to 50ºC for 15 minutes to ensure that no odours were attached to the sides of the vials. Odours were then concentrated by being absorbed for 30 minutes onto SPME fibres. Samples were then analysed by gas chromatography using a temperature gradient from 40 to 220ºC and a FID detector.

The average total peak area counts of odours in the air for five samples:

i. Without ionisation aroma total peak areas = 5,717
ii. With ionisation aroma total peak areas = 2,331

The reduction in odour levels in the Games Room due to smoke and other human and food odours due to ionisation was 59%. The major peaks found in these samples and which were reduced by ionization were typically from cigarette smoke.

3. Particulate Reduction

Particulate pollution is an important influence of both indoor and outdoor air quality, with risk-factors for loading, particle size and distribution. In these trials, the Aircode™ TA/TG-400 and CX-600 ionisation units were assessed to eliminate fine house-hold dust, acquired from domestic vacuum cleaner bags, and cigarette smoke particulates. A portable aerosol

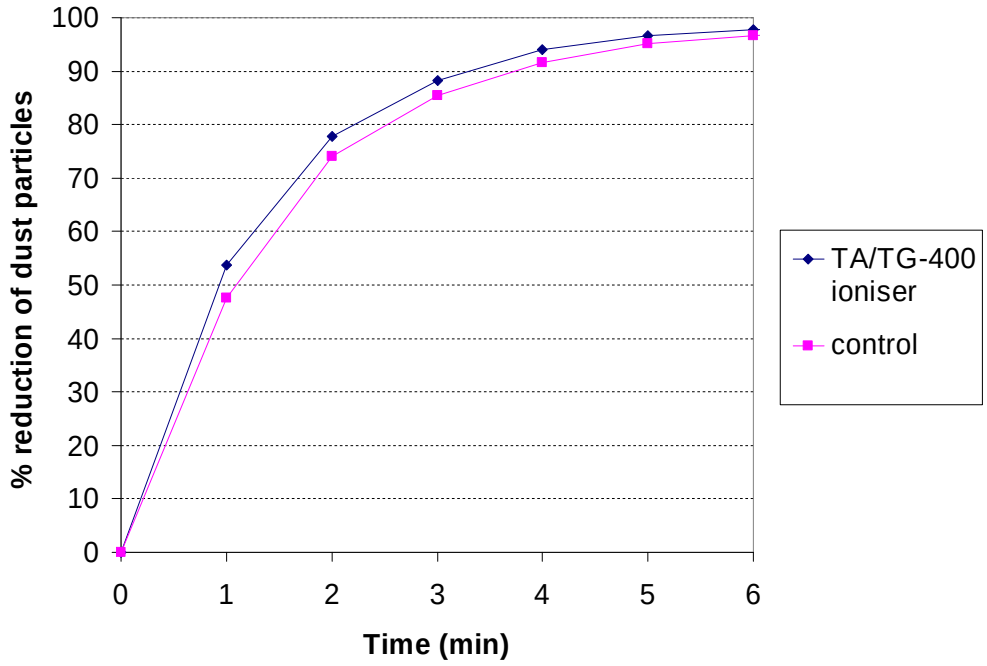
monitor (TSI 8520 DustTrak Monitor) was used to screen loading and size of air-borne particles (size range: 0.1 to 10 µm) with resolution of 1% of reading or 0.001 mg/m^3.

Dust particles

The TA/TG-400 unit was tested inside a covered glass tank (0.21 m^3) at a negative ion level of approximately 2,000 to 5,000 per cm^3. Using a short burst of compressed air, house-hold dust (0.3g) was rapidly dispersed in the tank and measured for dust dissemination with or without ionisation at 1 min intervals for 15 min. A small portable fan at low speed was also placed in the tank to ensure even distribution of negative ions. The CX-600 ionising unit was tested with the fan speed set at *ca.* ¼ and ionisation level at 3, providing negative ions of 12,000 to 18,000 ions/cm^3 within a room of approximately 30 m^3 volume. Dust (7g) was initially spread throughout the room using a rapid burst of compressed air. Results were compared to a control treatment with the same amount of dust and fan speed without ionisation.

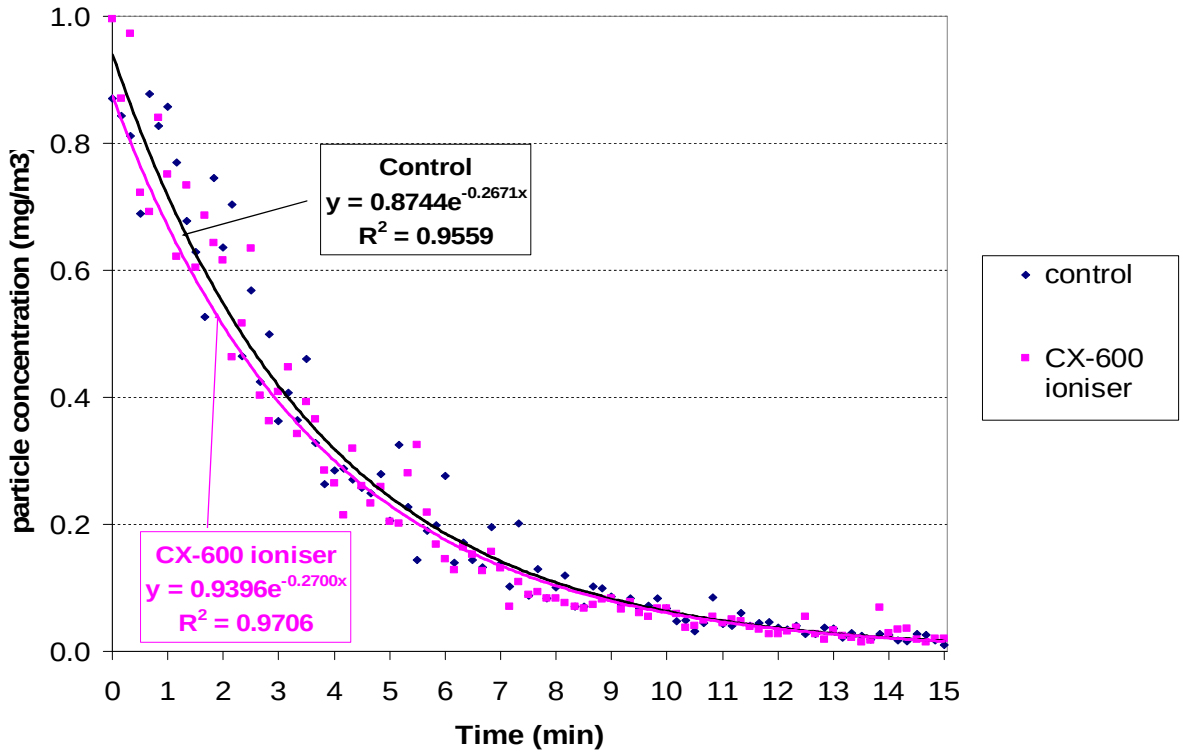
Results for the TA/TG-400 unit indicated a small effect of negative ions generated by the TA/TG-400 on dust particles 0.1-10µm in size, with the relative effect of the ionization unit declining over time (Fig. 6), from 13% relative reduction at 1 minute to down to 3% reduction at 3 minutes.

Fig.6 Ionisation treatment of dust particles (0.1-10µm diam.) using the TA/TG-400 unit. Values are means of 2 replicates.



However, ionisation by the CX-600 unit demonstrated to have an increased fall-out of dust particles during the initial stages of the trial (Fig. 7). For example at 2 minutes, the % rate of decay for the ionisation treatment and control was 44 and 37% respectively, with the ionisation resulting in a 19% greater reduction due to ionisation. However, by 8 min, there was virtually no difference in decay rates between the ionisation (89%) and control (88%).

Fig. 7 Ionisation treatment of dust particles (0.1-10µm diam.) using the CX-600 unit. Dust particle levels were logged at 10 sec intervals.

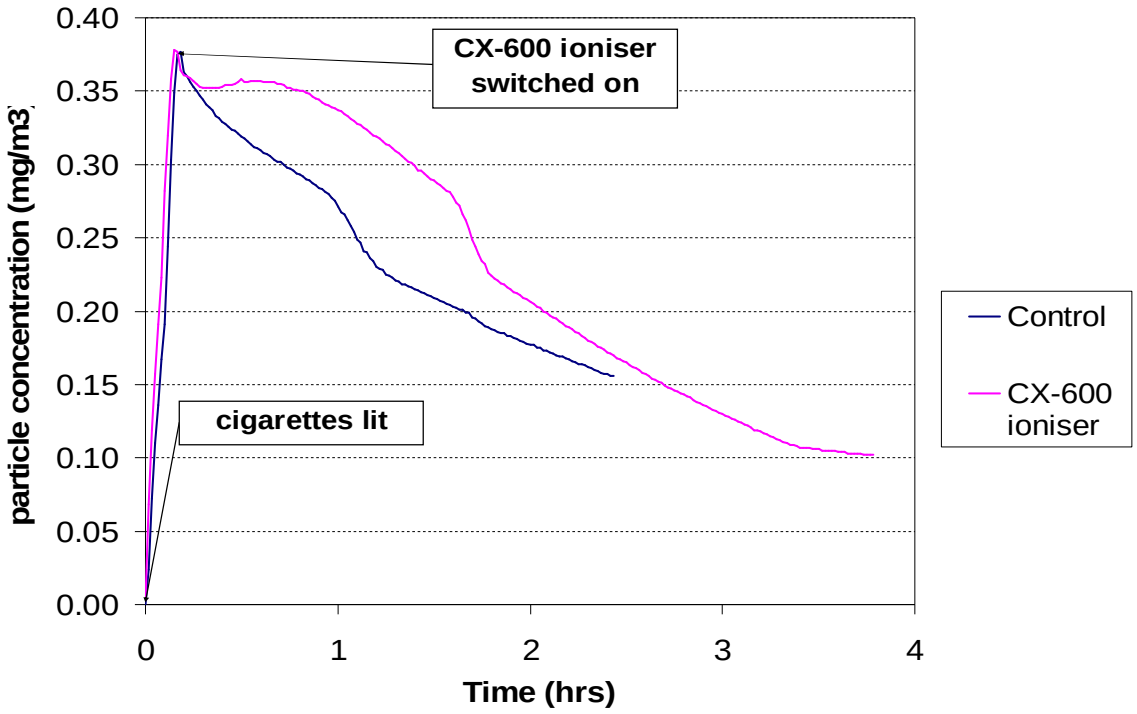


Cigarette smoke particles

The CX-600 unit was tested to remove cigarette smoke compounds, at a fan speed of *ca.* ¼ and ionisation setting of 3, which generated 12,000 to 18,000 ions/cm^3 within a closed room of approximately 30 m^3. Results were compared to a control treatment at the same fan speed (*ca.* ¼ setting) without ionisation. Two investigations were conducted, one test measuring smoke particles between 0.1 and 10µm in size, the other measuring smoke particle sizes of 0.1 to 1µm.

However, ionisation showed no effect on removing cigarette smoke for both particle size regimes for up to a 4 hour monitoring period (Fig. 8). As cigarette smoke particles are very small in size (it is reported that practically all freshly dispersed environmental tobacco smoke particle masses lie in the size range of 0.02-2µm, with the mass median diameters values around 0.2-0.7µm), perhaps any clumping of particles caused by ionisation was insufficient to promote settling of cigarette particular matter, in the manner of larger, heavier particles.

Fig. 8 Ionisation treatment of cigarette smoke using the CX-600 unit. Size range of smoke particles monitored was 0.1-10µm diam.



Air particles – Star City Casino
Air was passed through a Millipore 37mm Aerosol Analysis Monitor with 0.8 µm (MAWP037A0) at 4.5 L/min for 30 minutes using a vacuum pump in order to capture particles in the air. Particles embedded on the filters greater than 10µm were counted using a binocular microscope with 80x magnification.

i. Average particle count for no ionisation present was 533 / m^3,
ii. Average particle count for ionisation units turned on was 295/m^3.

This is a reduction in particles in the air down to almost a half (45%) of the previous levels due to the ionisation of the air.

However, both these air samples are relatively clean and fit within the outer limits of clean rooms as defined in British Standards BS 5295 for Class of Environmental Cleanliness Levels J (0 – 450 particles/m^3) and K (451 – 4500 particles/m^3). A larger difference due to ionization with more definite results, would be expected to occur with a higher particle load in the air.

Air particles – West Pennant Hills Sports Club
Two types of air monitoring equipment were used to test for the level of air-borne particles:

- TSI 8520 DustTrak Monitor - used to sample air-borne particles from size range 0.1 to 10 µm with resolution of 1% of reading or 0.001 mg/m^3, in various areas of the Games Room
- Millipore 37mm Aerosol Analysis Monitor - air was passed through the monitor with 0.8 µm filter (MAWP037A0) at 4.5 L/min for 30 minutes using a vacuum pump in order

to capture particles in the air. The aerosol monitor was positioned near the Bar/Lucky Wheel stand (sampling area B; see Appendix 1). Particles embedded on the filters greater than *ca.* 10µm were counted using a binocular microscope.

TSI 8520 DustTrak Monitor

Overall, there was a reduction in air-borne particles (0.1 to 10 µm in size) by about a half (49%) of the previous levels due to ionisation (Table 6). Sampling area A, which was situated in the top end of the games room (see Appendix 1) and considered by management as a problem zone for odours and stale air, showed the highest particle load (0.837 mg/m^3) when the ionisation unit was not operating. In deed in this problem area particular matter levels were more than double average level of the other four sampling location. When the ionisation unit was turned on particle levels in this problem area were reduced by 69%. This observation reinforces that made elsewhere, that the biggest effect of ionization technology is observed when air quality is a problem.

Table 6. Reduction in particulate levels in the air in various areas of the Games Room, West Pennant Hills Sports Club

Sampling areas	**No ionisation (mg/m^3)**	**With ionisation (mg/m^3)**	**% reduction due to ionisation**
A	0.837	0.256	***69%***
B	0.372	0.140	***62%***
C	0.627	0.418	***33%***
D	0.382	0.170	***56%***
E	0.242	0.186	***23%***
Average effect on particles			***49%***

Millipore Aerosol Analysis Monitor

Average particle counts near the Lucky Wheel (sampling point B, see Appendix 1) for:

- No ionisation present was 274 / m^3,
- Ionisation units turned on was 293 /m^3.

There appears to be no reduction in particles with size >10µm due to ionisation of the air, possibly because the conventional filters used in the air-conditioning system were able to remove larger particles (>10µm) from Games Room. However, conventional filters might not have ability to extract smaller air particles (<10µm), which were detected using the TSI 8520 DustTrak Monitor. The location of this type of air sampling testing which needed a powerful pump and air sampling on a stand was limited to one location in the room near the Lucky Wheel. Unfortunately, the air in this location was not always representative of the typical room air, as it was very close to an external door that was frequently opened for periods of time. Therefore, the lack of significant differences from these tests would be readily explained by the sampling location.

4. Ethylene reduction

A major limitation in extending the shelf-life of horticultural produce is the accumulation of ethylene gas in storage facilities or transport containers.
Ethylene can

(i) undesirably promote premature ripening or aging in climacteric fruits (*eg*. avocado) and

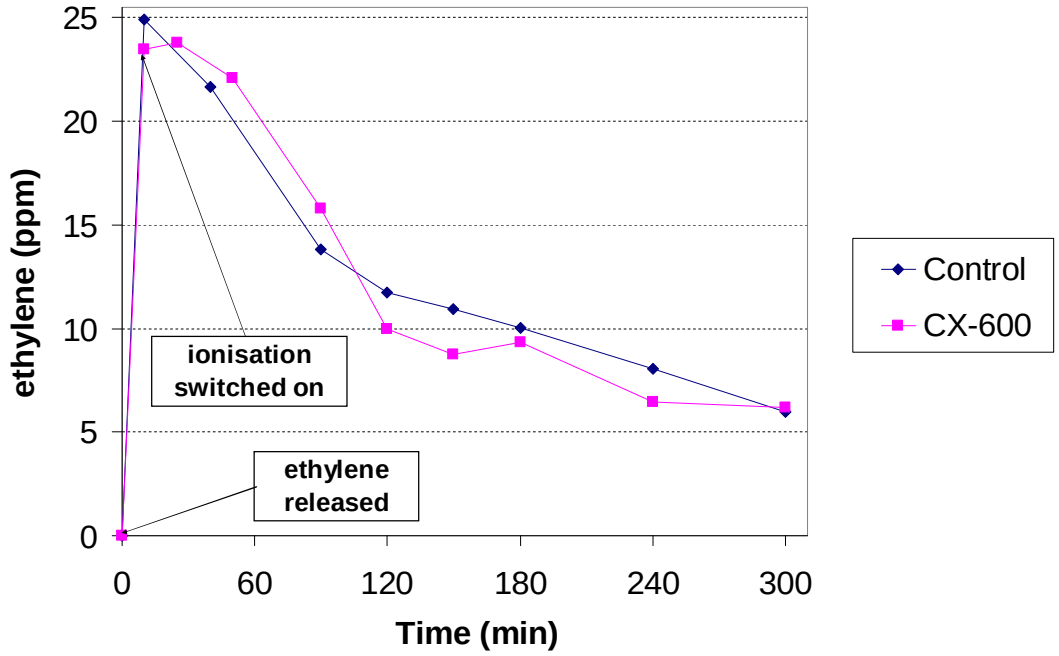
(ii) (ii) hasten the onset of senescence in non-climacteric produce (*eg*. broccoli), often exhibited as loss of green colour (chlorophyll destruction), detrimental changes in texture and flavour, and higher sensitivity to disorders and microbial decay.

This study aimed to test the ability of the CX-600 ionisation unit to eliminate ethylene gas within a semi-commercial storage facility.

The investigation was conducted with two different levels of exogenous ethylene, one at a hih test level of 23-25ppm and the other at a much lower level of 2.9-3ppm, which is similar to that found in cool rooms with high ethylene, within a closed room of approximately 30m^3 at ambient temperature (18 – 22ºC). The CX-600 ionising unit was operated with a fan speed of *ca*. ¼ and ionisation level at 3, providing negative ions of 12,000 to 18,000 ions/cm^3. A high powered fan was also used inside the room to ensure even dispersal of both ethylene and negative ions. After introducing the required ethylene dose, ethylene levels were sampled at various times and compared to ethylene decline in control treatments without any ionisation.

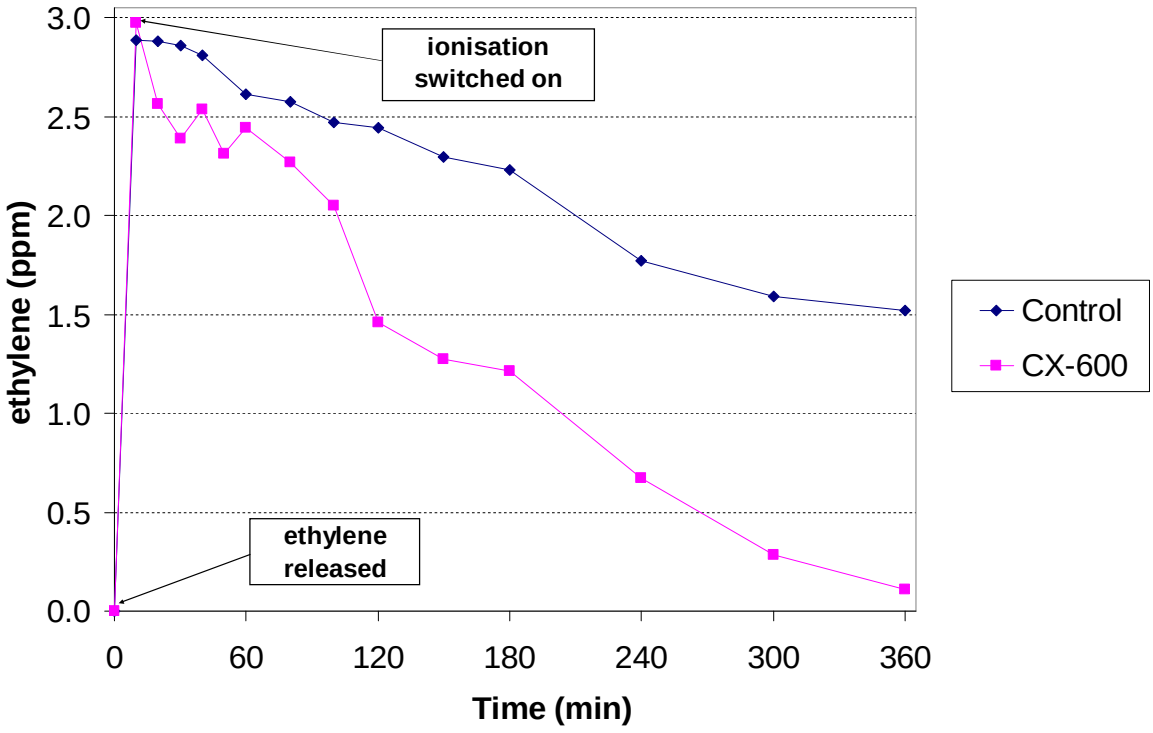
With an initial level of ethylene at 23-25ppm, the CX-600 unit had little effect in purifying the air. For example after 240min, the % loss rates of ethylene for the control (no ionisation) and during operation of the CX-600 unit were comparable at 68 and 72%, respectively (Fig. 9).

Fig. 9 Ionisation treatment of ethylene (24-25ppm) by the CX-600 unit. Each point represents an average of 4 measurements



However, when the trial was repeated using a lower initial level (2.9-3ppm) of ethylene, the CX-600 ionisation unit was very effective in eliminating ethylene gas (Fig. 10). After 3 hours or 180min, operating the CX-600 unit caused the ethylene level to drop by 59% or to 1.2ppm, compared with the control which had a natural decay rate of about 23%, or a an ethylene level of 2.2ppm, so after this time ethylene are almost halved by the CX-600. The capacity of the CX-600 unit to eliminate ethylene increases over time and by 6 hours (or 360 minutes) the ethylene levels were virtually eliminated by the CX-600 unit (residual level: 0.1ppm) a 96% reduction of the original ethylene levels. The ethylene levels were 93% lower than the natural decline, which still resulted in levels of 1.5ppm ethylene (or 47%) of the original level left after 6 hours. This means that under these conditions the CX-600 reduces ethylene more than 14 times more rapidly than would occur normally without the CX-600 unit.

Fig. 10 Ionisation treatment of ethylene (*ca*. 3ppm) by the CX-600 unit. Each point represents an average of 5 measurements



Conclusions

These results show that at the high ethylene levels that may be encountered in cool rooms of several ppm, the CX-600 ionisation unit can virtually eliminate ethylene over time. It is important that sufficient CX-600 capacity be added to the coolroom ,so that the ionization unit is not overwhelmed by extremely high levels of ethylene.

SYDNEY POSTHARVEST LABORATORY
Postal Address: PO Box 62, North Ryde, NSW 1670, AUSTRALIA
Street Address: CSIRO Food Science Australia Building, 11 Julius Avenue,
Riverside Corporate Park, North Ryde, NSW 2113, AUSTRALIA

Evaluation of CX-600 units for Ethylene Reduction in a Semi-Commercial Storage Facility.

Stephen Morris & Michael Forbes-Smith
Sydney Postharvest Laboratory
6 September 2006

Summary

At the higher expected levels of ethylene in cool rooms of several ppm, the CX-600 ionisation unit reduced ethylene from 3 ppm to almost zero (0.1 ppm) over several hours. The decline in ethylene due to the CX-600 unit was almost 15 times more rapid than without the CX-600 unit.

It is important that sufficient ionization be matched to the ethylene level in the room as the CX-600 has trouble effectively reducing ethylene if ethylene become extremely high.

Background

A major limitation in extending the shelf-life of horticultural produce is the accumulation of ethylene gas in storage facilities or transport containers.
Ethylene can

(i) undesirably promote premature ripening or aging in climacteric fruits (*eg*. avocado) and
(ii) hasten the onset of senescence in non-climacteric produce (*eg*. broccoli), often exhibited as loss of green colour (chlorophyll destruction), detrimental changes in texture and flavour, and higher sensitivity to disorders and microbial decay.

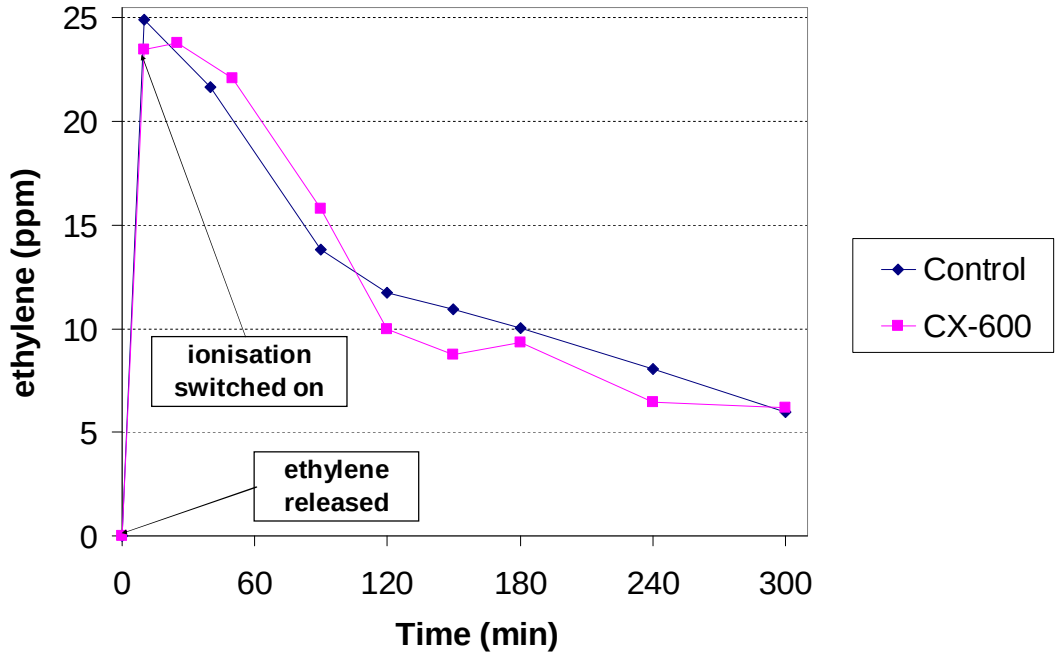
This study aimed to test the ability of the CX-600 ionisation unit to eliminate ethylene gas within a semi-commercial storage facility.

The investigation was conducted with two different levels of exogenous ethylene, one at a high test level of 23-25ppm and the other at a much lower level of 2.9-3ppm (similar to that found in cool rooms with high ethylene). Tests were done within a closed control temperature room of approximately 30m^3 at a temperature of 20ºC. The CX-600 ionising unit was operated with a fan speed of *ca*. ¼ and ionisation level at 3, providing negative ions of 12,000 to 18,000 ions/cm^3. A high powered fan was also used inside the room to ensure an even dispersal of both ethylene and negative ions. After introducing the required ethylene dose, ethylene levels were sampled at various times and compared to ethylene decline in control treatments without any ionisation.

Results

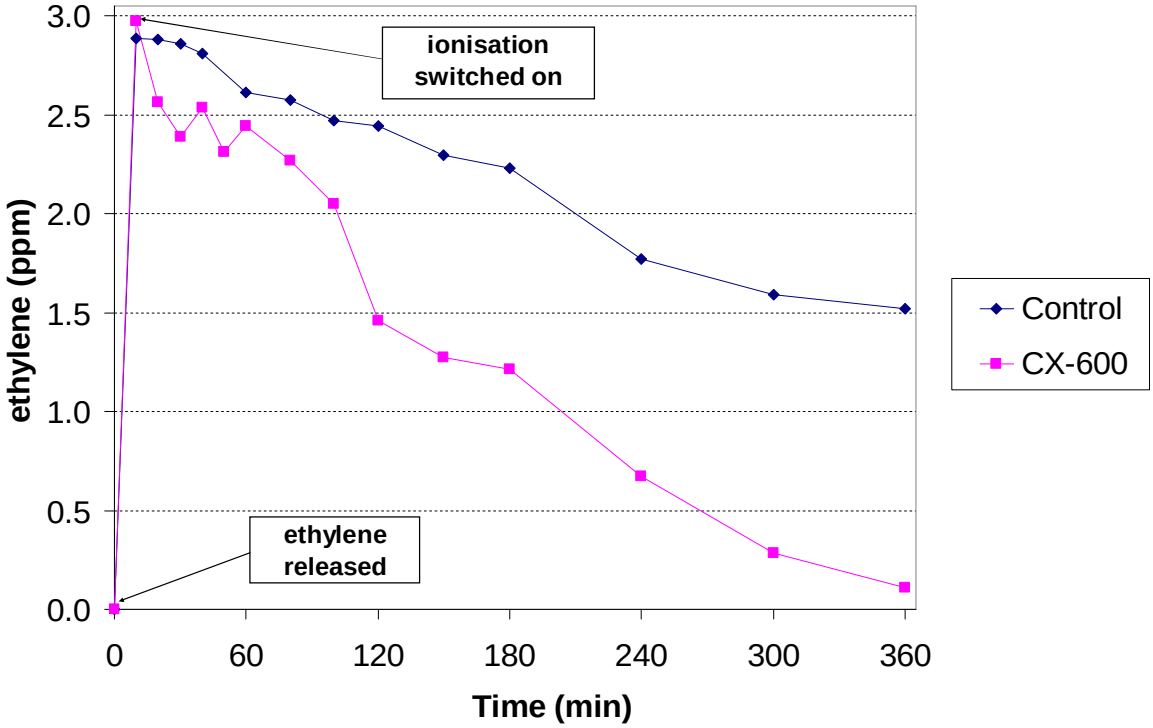
With an initial level of ethylene at 23-25ppm, the CX-600 unit had little effect in purifying the air. For example after 240min, the % loss rates of ethylene for the control (no ionisation) and during operation of the CX-600 unit were comparable at 68 and 72%, respectively (Fig 9).

Fig. 9 Ionisation treatment of ethylene (24-25ppm) by the CX-600 unit. Each point represents an average of 4 measurements



However, when the trial was repeated using a lower initial level (2.9-3ppm) of ethylene, the CX-600 ionisation unit was very effective in eliminating ethylene gas (Fig. 10). After 3 hours or 180min, operating the CX-600 unit caused the ethylene level to drop by 59% or to 1.2ppm, compared with the control which had a natural decay rate of about 23%, or a an ethylene level of 2.2ppm, so after this time ethylene are almost halved by the CX-600. The capacity of the CX-600 unit to eliminate ethylene increases over time and by 6 hours (or 360 minutes) the ethylene levels were virtually eliminated by the CX-600 unit (residual level: 0.1ppm) a 96% reduction of the original ethylene levels. The ethylene levels were 93% lower than the natural decline, which still resulted in levels of 1.5ppm ethylene (or 47%) of the original level left after 6 hours. This means that under these conditions the CX-600 reduces ethylene more than 14 times more rapidly than would occur normally without the CX-600 unit.

Fig. 10 Ionisation treatment of ethylene (*ca*. 3ppm) by the CX-600 unit. Each point represents an average of 5 measurements



Conclusions

These results show that at the high ethylene levels that may be encountered in cool rooms of several ppm, the CX-600 ionisation unit can virtually eliminate ethylene over time. It is important that sufficient CX-600 capacity be added to the coolroom to ensure that the units are not overwhelmed by extremely high levels of ethylene.

Signed

Dr Stephen Morris

SYDNEY POSTHARVEST LABORATORY
Postal Address: PO Box 62, North Ryde, NSW 1670, AUSTRALIA
Street Address: CSIRO Food Science Australia Building, 11 Julius Avenue, Riverside Corporate Park, North Ryde, NSW 2113, AUSTRALIA

Evaluation of ID-500 Units Installed in Air Conditioning at Star City Casino, VIP Lounge.

Stephen Morris & Michael Forbes-Smith
Sydney Postharvest Laboratory
July 24, 2006

Summary

Ionisation of the air in the VIP Room at Star City Casino, resulted in

i. a reduction of bacteria levels in the air by 52%
ii. a reduction in dust particles by 45%
iii. no change in human, food or smoke odours
iv. no detectable levels of ozone (<0.003 ppm) in both the ducts and VIP Room.

The tests were performed when the usage of the room was low, if tests had been done when the usage of the room was high, the differences in air quality due to ionization would have been expected to be much larger.

Background

The effect of ionisation on air quality by two ID-500 ionisation units installed in the air conditioning ducting was examined at Star City Casino, VIP Lounge. The air to this area is not recirculated, but instead supplied at a rate of about 24,000 litres/min into a room of approximately 1,100 m^3 volume, this means that the air in the VIP lounge is fully replaced about every 40 minutes. There had been problems with odours and air quality in this room and the ionization technology was installed to attempt to improve the air quality.

A variety of tests were performed to determine the air quality in the room by sampling from numerous locations throughout the room. Tests were done with the ionization machines turned off and then with the ionization turned on. These tests included

- Air-borne microorganisms, both mould (using MEA agar) and bacteria (using NA agar)
- Air particles (dust and fibres etc) – particles >10µm per m^3
- Odours – the sampling and analysis methods used (gas chromatography and SPME sampling) can monitor a range of human, food and smoke odours in the air.
- Ozone production using two technologies
  - i a portable meter based on gas sensitive semiconductors and
  - ii chemical reactive tubes using Draeger gas sampling and analysis technology.

The tests were performed in the VIP room and the two air conditioning ducts supplying these rooms between 6.30 and 8.30 am on the mornings of Wednesday the 5th and Thursday the 6th of July, and with follow up ozone tests on Tuesday the 18th July. At this time of the day, the number of patrons in the room was very low, with a maximum of fifteen patrons and a maximum of five staff in the room during this time. The ionisation units were turned off one hour prior to the no ionization tests (which may result in some carryover benefit from

ionization effects), while for the ionization tests the units had been running for over 18 hours.

Results

1. Air-borne microorganisms

Petri dishes containing different media to promote bacterial and mould growth (Nutrient Agar and Malt Extract Agar, respectively) were exposed to the air for various times with and without ionisation in the VIP lounge, Star City Casino.

When all times were averaged, the bacterial levels in the air were reduced on average by more than 50% when the ionization unit was running (Table 1), while the reduction in mould levels was lower at only 9% on average. For more definitive results, further collection of air-borne microorganisms is recommended at longer exposure times, particularly when there is a high load of persons in the area.

Table 1. Reduction in mould and bacteria in the air in the VIP room, Star City Casino.

Time the test plate was exposed (minutes)	**No ionization (per plate)**	**With ionization (per plate)**	**% reduction due to ionization**
Mould			
0.03	0.25	0.25	0%
1:00	0.5	0	100%
3:00	0	0	0%
10:00	0.75	1	-33%
30:00	1.25	1.5	-20%
Average effect on mould			***9% reduction***
Bacteria			
0:03	0.5	0	100%
1:00	1.25	0.25	80%
3:00	0.5	0.5	0%
10:00	1	0.5	50%
30:00	3.25	2.25	31%
Average effect on bacteria			***52% reduction***

2. Air particles

Air was passed through a Millipore 37mm Aerosol Analysis Monitor with 0.8 µm (MAWP037A0) at 4.5 L/min for 30 minutes using a vacuum pump in order to capture particles in the air. Particles embedded on the filters greater than 10µm were counted using a binocular microscope with 80x magnification.

iii. Average particle count for no ionisation present was 533 / m^3,
iv. Average particle count for ionisation units turned on was 295/m^3.

This is a reduction in particles in the air down to almost a half (45%) of the previous levels due to the ionisation of the air.

However, both these air samples are relatively clean and fit within the outer limits of clean rooms as defined in British Standards BS 5295 for Class of Environmental Cleanliness Levels J (0 – 450 particles/m^3) and K (451 – 4500 particles/m^3). A larger difference due to ionization with more definite results, would be expected to occur with a higher particle load in the air.

3. Odours

Air at the casino was sampled in 45ml vials, which were exposed to the air for 60 minutes before being sealed. Prior to analysis for odours, the vials were heated to 50C for 15 minutes to ensure that no odours were attached to the sides of the vials. Odours were then concentrated by being absorbed for 30 minutes onto SPME fibres. Samples were then analysed by gas chromatography using a temperature gradient from 40 to 220C and a FID detector.

Average total peak area counts of aromas in the air for eight samples

i. Without ionisation aroma total peak areas = 6220
ii. With ionisation aroma total peak areas = 6555

There is no significant difference in aromas in the air with or without air ionisation. The levels of human, food and smoke odours or aromas in the air were very low and hence do not allow significant differences to be fully tested determined. More definite results would be expected if air samples were taken when the air was recognizably tainted (*eg.* during garbage collection times near air intakes ducts) or when a large number of people were present in the room.

4. Ozone

Two types of ozone detecting equipment were used namely the Draeger Multi Gas Detector Draeger ozone gas tubes (Part No. 6733181) based on sampling a precise volume of air and a specific reaction with chemical agents and the Aeroqual Ozone Series 500 Ozone Monitor based on gas sensitive semiconductor technology.

Since slightly different results were obtained by each technology at very low ozone levels, they were tested under a range of ozone levels (Table 2). It seems that for moderate to low ozone levels ($\geq$ 0.1 ppm) electronic based ozone meters based on gas sensitive semiconductors are adequate and very similar to Draeger Tube values. However, for low to very low ozone levels of $\leq$ 0.05 ppm and especially for ozone free air Draeger gas tubes are much more accurate.

Table 2 Comparison of Two Ozone Measurement Technologies for Accuracy at Different Ozone Levels

Ozone Level ppm	Aeroqual Series 500 Ozone Monitor			Draeger Ozone Tubes	
	Average ppm (over 10 min)	Minimum	Maximum	Sample Size ml	Value ppm
0.000 (ozone free)	0.025	0.000	0.046	1,000	< 0.001
~ 0.1 ppm	0.118	0.081	0.126	100, 200	0.125
~ 0.5 ppm	0.526	0.489	0.566	100	0.55

Ozone measurements were made in the two ducts through access ports and in the centre of the ducts. In the VIP Room ozone measurements were made at chest level under the air delivery vents and in the centre of the room half way between the delivery and air return vents. The results are described in Table 3. The most accurate measurements based on the tests performed at standard ozone levels are with the Draeger tubes, these show that ozone is below measurable levels of 0.003 ppm in both the ducts and the VIP room.

Table 3 Ozone Levels detected in Air Conditioning Ducts and VIP Room at Star City Casino by Two Ozone Measurement Technologies

Location	Aeroqual Series 500 Ozone Monitor			Draeger Ozone Tubes	
	Average ppm (over 5 min)	Minimum	Maximum	Sample Size ml	Value ppm
Duct 1	0.005	0.000	0.009	300	< 0.003
Duct 2	0.004	0.000	0.011	300	< 0.003
VIP Room, air delivery	0.021	0.000	0.043	300	< 0.003
VIP Room, centre of room				300	<0.003

The Aeroqual Ozone Monitor indicated that in the ducts ozone levels were very low and that they were no different from a zero ozone level, within the limit of accuracy for the meter of ±0.010 ppm. In the VIP Room, the Aeroqual Ozone Monitor gave one of the eight ozone readings as 0.043 ppm, which resulted in an average ozone of 0.021 ppm. This value is incorrect for two reasons, firstly the Draeger Ozone tubes are more accurate at these low levels and secondly the highest ozone levels if generated by the air ionizer must be in the air ducts, which are diluted down in the room as the air is replaced every approximately 40 minutes. Therefore, room ozone levels in the room must be lower than the ozone levels in the air duct.

In summary, ozone levels in both the ducts and the VIP Room are below the lower detection limits of the Draeger Ozone Tubes of 0.003 ppm ozone. Ozone levels in the room are therefore well below the maximum eight hour limit of 0.1 ppm ozone, as they are below the most accurate limit of detection, which is less than 3% of the current Australian standard limit for ozone.

Signed

Dr Stephen Morris

SYDNEY POSTHARVEST LABORATORY

Postal Address: PO Box 62, North Ryde, NSW 1670, AUSTRALIA
Street Address: CSIRO Food Science Australia Building, 11 Julius Avenue,
Riverside Corporate Park, North Ryde, NSW 2113, AUSTRALIA

Evaluation of Air Quality and Effects of a ID-500 Ionisation Units (AIRganix) Installed in Air Conditioning at West Pennant Hills Sports Club, Games Room

Stephen Morris & Michael Forbes-Smith
Sydney Postharvest Laboratory
August 3, 2006

Summary

The ionisation of the air by the ionisation units (AIRganix) units in the Games Room resulted in:

i. a reduction of bacteria levels in the air by 49%
ii. a reduction of mould levels in the air by 23%
iii. air borne particles were reduced by 49%
iv. odours in the air due to smoke and other smells were reduced by 59%
v. ozone levels due to the ionisation units were below detection limits of 0.003 ppm which is less than 1/30th of the maximum allowable ozone levels of 0.1ppm

Background

The effect of ionisation on air quality by an ID-500 ionisation unit (AIRganix) installed in the air conditioning ducting was examined in the Games Room at West Pennant Hills Sports Club. There had been problems with odours and air-borne particulates (*eg*. cigarette smoke) in this room and the ionisation technology was installed to attempt to cleanse the air.

A variety of tests were performed to determine the air quality in the room by sampling from various locations throughout the room. Tests were done with the ionisation machine turned off and then with the ionisation turned on. These tests included:

- Air-borne microorganisms, both moulds and bacteria
- Air particles (dust, fibres, smoke particulates etc) >0.1 µm in size
- Odours – the sampling and analysis methods used (gas chromatography and SPME sampling) can monitor a range of human, food and smoke odours in the air.
- Ozone production using Draeger gas sampling and analysis technology.

The tests were performed in the Games Room between 6:00 pm and 8:30 pm on Friday 21st July and Saturday 22nd July, time periods when the number of patrons in the room was very high and activity was busy. The ionisation units were turned off 20 hours prior to the no ionisation tests (to ensure no carryover from potential ionisation effects), while for the ionisation tests the units had been running for over 20 hours.

Results

1. Air-borne microorganisms

Petri dishes containing Nutrient Agar medium to promote microbial growth were exposed to the air for various times with and without ionisation in the Games Room, West Pennant Hills Sports Club.

When all times were averaged, the bacterial levels in the air were reduced on average by more than 49% when the ionisation unit was running (Table 1), while the reduction in mould levels was lower at only 23% on average. Total reduction of air-borne microorganisms while the ionisation unit was operating was 45%.

Table 1. Reduction in mould and bacteria in the air in the Games Room, West Pennant Hills Sports Club

Time the test plate was exposed (minutes)	**No ionisation (per plate)**	**With ionisation (per plate)**	**% reduction due to ionisation**
Mould			
30 min	1.9	1.6	***16%***
60 min	3.7	2.6	***30%***
Average effect on mould			***23% reduction***
Bacteria			
30 min	9.4	4.3	***54%***
60 min	18.0	10.1	***44%***
Average effect on bacteria			***49% reduction***
All microorganisms			
30 min	11.3	5.9	***48%***
60 min	21.7	12.7	***42%***
Average effect on microorganisms			***45% reduction***

2. Air particles

Two types of air monitoring equipment were used to test for the level of air-borne particles:

- TSI 8520 DustTrak Monitor - used to sample air-borne particles from size range 0.1 to 10 µm with resolution of 1% of reading or 0.001 mg/m^3, in various areas of the Games Room
- Millipore 37mm Aerosol Analysis Monitor - air was passed through the monitor with 0.8 µm filter (MAWP037A0) at 4.5 L/min for 30 minutes using a vacuum pump in order to capture particles in the air. The aerosol monitor was positioned near the Bar/Lucky Wheel stand (sampling area B; see Appendix 1). Particles embedded on the filters greater than *ca.* 10µm were counted using a binocular microscope.

TSI 8520 DustTrak Monitor

Overall, there was a reduction in air-borne particles (0.1 to 10 µm in size) by about a half (49%) of the previous levels due to ionisation (Table 2). Sampling area A, which was situated in the top end of the games room (see Appendix 1) and considered by management as a problem zone for odours and stale air, showed the highest particle load (0.837 mg/m^3) when the ionisation unit was not operating. In deed in this problem area particular matter levels were more than double average level of the other four sampling location. When the ionisation unit was turned on particle levels in this problem area were reduced by 69%. This observation reinforces that made elsewhere, that the biggest effect of ionization technology is observed when air quality is a problem.

Table 2. Reduction in particulate levels in the air in various areas of the Games Room, West Pennant Hills Sports Club

Sampling areas	**No ionisation (mg/m^3)**	**With ionisation (mg/m^3)**	**% reduction due to ionisation**
A	0.837	0.256	***69%***
B	0.372	0.140	***62%***
C	0.627	0.418	***33%***
D	0.382	0.170	***56%***
E	0.242	0.186	***23%***
Average effect on particles			***49%***

Millipore Aerosol Analysis Monitor

Average particle counts near the Lucky Wheel (sampling point B, see Appendix 1) for:

- No ionisation present was 274 / m^3,
- Ionisation units turned on was 293 /m^3.

There appears to be no reduction in particles with size >10µm due to ionisation of the air, possibly because the conventional filters used in the air-conditioning system were able to remove larger particles (>10µm) from Games Room. However, conventional filters might not have ability to extract smaller air particles (<10µm), which were detected using the TSI 8520 DustTrak Monitor. The location of this type of air sampling testing which needed a powerful pump and air sampling on a stand was limited to one location in the room near the Lucky Wheel. Unfortunately, the air in this location was not always representative of the typical room air, as it was very close to an external door that was frequently opened for periods of time. Therefore, the lack of significant differences from these tests would be readily explained by the sampling location.

3. Smoke and Odours

Air at the casino was sampled in 45ml vials, which were exposed to the air for 60 minutes before being sealed. Prior to analysis for odours, the vials were heated to 50ºC for 15 minutes to ensure that no odours were attached to the sides of the vials. Odours were then concentrated by being absorbed for 30 minutes onto SPME fibres. Samples were then analysed by gas chromatography using a temperature gradient from 40 to 220ºC and a FID detector.

The average total peak area counts of odours in the air for five samples:

i. Without ionisation aroma total peak areas = 5,717
ii. With ionisation aroma total peak areas = 2,331

The reduction in odour levels in the Games Room due to smoke and other human and food odours due to ionisation was 59%. The major peaks found in these samples and which were reduced by ionization were typically from cigarette smoke.

4. Ozone

Ozone in the Games Lounge which had a CX-600 ionisation unit in the airconditioning was sampled using a Draeger Multi Gas Detector. Draeger ozone gas tubes (Part No. 6733181) based on sampling a precise volume of air and a specific reaction with chemical agents. For low to very low ozone levels of ≤ 0.05 ppm and especially for ozone free air Draeger gas tubes are very accurate, and considerably more accurate than commonly used electronic meters.

Results showed that ozone in the Games Lounge was below measurable levels of 0.003 ppm during the sampling periods, including Saturday evening when the ionisation unit was turned on. Ozone levels in the room are therefore well below the maximum eight hour limit of 0.1 ppm ozone, as they are below the most accurate limit of detection, which is less than 3% of the current Australian standard limit for ozone, or less than $1/30^{th}$ of maximum safe levels.

Additionally ozone sampling was carried out in the Lounge room adjacent to the Games room. The air was purified in this room with an EULOQUEST Eagle 500 ionisation unit. Ozone levels were 0.008 ppm ozone immediately in front of the unit and <0.003 ppm in the centre of the room, giving an average of about 0.005 ppm ozone in the Lounge area. This is 5% of the current Australian standard limit for ozone, or $1/20^{th}$ of maximum safe levels.

Signed

Dr Stephen Morris
Managing Director

Appendix. 1

General schematic of the Games Room, West Pennant Hills Sports Club, and sampling sites for odours (1,2,3,4,5,6), microorganisms (i, ii, iii, iv, v, vi, vii), and air-borne particulates of 0.1-10µm in size (A, B, C, D, E) and >10µm in size (Δ). Poker machines areas are designated as