IAQ PROFILE

Kee-Neng Wai Ph.D.
Hinds International (HK) Ltd.
Hong Kong

SUMMARY

IAQ Profile is a visual presentation of indoor air quality. In profiling IAQ, full recognition is given to time as a dimension and the air-quality parameters to be measured are specified. Utilizing state-of-the-art technology in automatic air monitoring, data logging, computerization and information technology, IAQ profiling is quantitative and can be accurate, precise, labour saving and cost effective. Examples are given to illustrate that IAQ Profiles of air-conditioned indoor environments are reproducible from day to day and at different measurement points, which enables IAQ Profile to be used as a standard for communication and for indoor air management, controls and legislation.

Key words: IAQ Profile, cost effectiveness, accuracy, reproducibility, indoor environmental management, legislation

INTRODUCTION

An IAQ Profile is a visual presentation of indoor air quality. A good IAQ Profile describes precisely changes in concentration levels of selected air quality parameters in an indoor environment over a period of time. In profiling IAQ, one must specify the air quality parameter(s) to be monitored and give full recognition to time as a dimension. Real time monitors with state-of-the-art sensing, automatic sampling and data-logging features must be used. A desktop or notebook computer with suitable software can be used to download the IAQ data and for production of IAQ Profiles.

The IAQ Profiles of all modern office buildings and commercial centers, which are air conditioned with mechanical ventilation controls, are reproducible from day to day and are different from one building to another, depending on how the building is managed and utilized. The air quality information of an IAQ Profile, in graphic form as well as in the form of original air quality data with statistical analysis, can be transmitted by computer network, radio-transmission or telephone line to the service centre of the building or to a remote air quality control centre to be stored as a permanent record for future reference, utilized for IAQ management or used for IAQ legislation and control.

NOMENCLATURE AND PROFILE INFORMATION

To be used in building management and for legislation and control, an IAQ Profile should be specified with profile information to include the following:-

- Profile type, i.e., IAQ (No. of Parameter(s), Duration) Profile
- Place and location

- Date, time and duration
- The air quality parameter(s) measured
- Sampling frequency
- Instrument used

Illustrations are given below.

IAQ(1P8H) Profile

Figure 1 is the IAQ(1P8H) Profiles on formaldehyde and the profile statistics of an office located at Tai Koo Shing, Hong Kong, taken on June 4, 2001, by two units of PPM Formaldemeter (S/N 204-1651 and 205-1652) running in parallel and concurrently to take samples at every 1 minute interval for 8 hours.

(Note: Parallel runs to demonstrate precision of the instrument and reproducibility of the profile.)

IAQ(5P24H) Profile

Figure 2 is an IAQ(5P24H) Profile on temperature, RH, CO_2, CO and NO_2 of an architect's general office on the 9th Floor of a commercial building in Wanchai, Hong Kong, taken on May 19th 2000 with a YES205 Monitor (S/N C-525) placed in front of the air-return louver of the central air-conditioner monitoring and recording the levels of all 5 IAQ parameters at every 5 minute intervals for 24 hours.

An IAQ Profile may include as many parameters as needed. For the sake of clarity, in practice, 5P's are often the maximum number of parameters included in a single profile. With digital technology, a profile of any time and duration in minutes, hours or days can be recalled from the data bank for visual presentation, statistical analysis and interpretation of the air quality monitored.

INSTRUMENTATION

Two sets of PPM Formaldemeter and Monitor Station were employed to produce the Formaldehyde profiles of this work. The instrument was custom-designed and built with a high sensitivity electro-chemical sensor, microprocessor, timer, printer, as well as automatic sampling and data logging features for the monitoring of formaldehyde in air quantitatively at the concentration level of 400 ppb and below. The instruments were calibrated against reference standards in accordance with the procedure specified by the manufacturer. Both calibrated units were switched on to run continuously in a laboratory (with clean air) before and after they were taken out on each occasion of field service. Both units demonstrated good stability as no apparent shifting in calibration had been observed before and after the units were taken out for field service.

Six units of YES205 Air Quality monitor were employed to produce the 5P profiles of this work. The instruments were custom built to enable automatic and simultaneous monitoring and data logging of the levels of five Primary IAQ Parameters, namely temperature, RH, CO_2, CO and NO_2. The instrument has a Precision-calibrated NTC themistor for temperature sensing, a capacitive polymer sensor for the measurement of RH, a dual beam absorption

infrared sensor for the measurement of CO_2 and electro-chemical sensors for the measurement of CO and NO_2. Factory calibration of the instrument was done by the manufacturer for temperature and RH measurements. Zero calibrations of CO_2, CO and NO_2 measurements on zero gas (99.99% pure nitrogen gas) were conducted in our laboratory in accordance with the procedure specified by the manufacturer. The base lines of CO and NO_2 zero calibrations were set slightly above the X–axis to avoid superimposing of the two curves and to enable shifting and drifting to be observed, and corrections to be made.

Span calibration for carbon dioxide measurement was done with calibration gas at 1,000 ppm in accordance with the procedure specified by the manufacturer. After calibration in the laboratory, all six units were placed in operation on a shelf (with clean air) until taken out for field service and to be returned to the shelf afterwards and maintained in an operation mode. An IAQ(5P7D) Profile recorded by each instrument was taken out once a week for inspection of possible mal-functions and drifting of calibrations.

APPLICATION EXAMPLES

Example 1. IAQ Profiles of An Engineering Office in A Multi-story Industrial Building in Quarry Bay, Hong Kong. (Figures 3 & 4)

Five units of YES205 Air Quality Monitors were placed at selected locations (as marked on layout plan in Figure 3) to monitor independently and simultaneously the air quality of this engineering office (occupancy: 27) located on the 6th floor of an industrial building in Quarry Bay, Hong Kong for two consecutive days. The IAQ(5P48H) Profiles produced (Figure 4) have effectively illustrated the following: -

1. Reproducibility of IAQ Profiles is clearly demonstrated by the close resemblance of all 5 IAQ Profiles produced by 5 monitors operating simultaneously and independently for 2 consecutive days at selected locations of the premises.

2. The temperature curves of all five IAQ Profiles reflect instantaneous responses to the “on” and “off”’ of the central air-conditioner, as well as thermostatic controlling of the air-conditioning system. The profiles have revealed possible malfunctioning of the thermostatic control. (Note: The faulty thermostat has since been replaced.)

3. Rapid rise of CO_2 level at the start of a working day is clearly reflected in all five IAQ Profiles. The CO_2 curves in all five IAQ Profiles have also demonstrated the effectiveness of the fresh air booster fans. The fans were intentionally turned off during office hours of Nov. 21$^{st.}$ The result is that the peak CO_2 levels have exceeded 800 ppm during that day, as demonstrated and positively confirmed by all five IAQ Profiles.

4. The CO curves of all five IAQ Profiles have clearly shown that the CO level rises slightly during the daytime and drops at night, although these levels (below 1 ppm) are well below the Government’s current recommended level for good indoor air quality. This illustrates and confirms the high sensitivity of the test instrument.

Example 2. IAQ Profiles of An Accountant’s Office in A Commercial Building in Central District of Hong Kong (Figures 5, 6 & 7).

Four units of YES205 Air Quality Monitors were placed at selected locations (as marked on the layout plan in Figure 5) to monitor independently and simultaneously the levels of 5 Primary air parameters of the general office (occupancy: 40) and the Office Manager's office (occupancy: 1) of an accountant firm located on the 11^{h} floor of a commercial building in the Central District of Hong Kong for two consecutive days. The IAQ(5P48H) Profiles recorded are shown in Figure 6.

Concurrently, two sets of PPM Formaldemeter, operating in parallel, were placed in the general office to check the formaldehyde level over the entire two-day period. The IAQ(1P48H) Profile on formaldehyde and the profile statistics are shown in Figure 7. These profiles illustrate the following: -

1. The IAQ(5P48H) Profiles clearly reflect that the office has two air-conditioning zones with 2 separate air-handling units and air duct systems. (Monitors A & B were placed in Zone I, and Monitors C & D were placed in Zone II.)

2. The accuracy and reproducibility of these IAQ Profiles are clearly demonstrated by the remarkable closeness of the two IAQ(5P48H) Profiles, Profile A and Profile B, both of which were recorded in Zone I of the open office. Profile C, which was obtained in Zone II, has shown some deviations from Profiles A & B. Nonetheless, all these Profiles bear resemblance in many critical points because they were captured in the same open office, albeit at different locations.

3. The temperature, RH and CO_2 curves of Profile D indicate that between 15:00 and 19:00 hours on May 30th, the Office Manager had left the office, turned off the room air-conditioner, and closed the room door; the same three curves also indicate that between 10:00 to 18:00 hours on May 31st, someone was in the office, with the room air-conditioner turned off and the door opened. This is an illustration to show that IAQ Profile is responsive to the management and usage of the space.

4. The CO_2 curves show clearly and affirmatively that the air quality of this office has failed to meet with the standard of good air quality for the protection of workers, for which, 1,000 ppm of CO_2 is regarded as the upper limit. This is likely due to insufficient fresh air intake for the number of occupants. This shows that IAQ Profile offers a reliable standard based on which IAQ legislation can be established.

(Note: Immediate revelation of Sick Building Syndrome (SBS) associated with high CO_2 level are drowsiness, shortness of breath, increased pulse rate and cold sweating; long term syndrome are muscle pains and aches, tiredness, respiratory illness and hypertension.)

5. Temperature curves of all four IAQ Profiles indicate grossly inadequate thermostatic control of the air conditioning system. Profile C shows that room temperature consistently falls below 20^{o}C in the morning hours. Although temperature changes are well tolerated by the human body, running an office at such temperature may cause diminished productivity for some individuals. Suffice to say, energy wastage is high.

6. The IAQ(1P48H) Profile of Figure 7 demonstrates that the formaldehyde level of the premises during office hours is about 5-folds above the level of recommended good air quality by the Government of Hong Kong; at night it is 10-folds over. This calls for

improved ventilation for the premises with increase fresh air supply in order to reduce the formaldehyde level.

(Note: Vapor of formaldehyde is known to cause eye, nose and respiratory irritation and sensitization. Most importantly, as we are repeatedly warned by the HK Government, formaldehyde is a suspected human carcinogen.)

7. The reliability of formaldehyde measurements recorded by the IAQ(1P48H) Profile in Figure 7 is fully demonstrated by the results and statistical analyses of data obtained from the parallel run of the two units. The 48 Hour Profile is obtained by joining six 8-hour Profiles. The built-in software performs the statistical calculations and presentations shown below the graph in Figure 7, hence, human bias is eliminated.

8. Good agreement between the IAQ(1P48H) Profile (Figure 7) and the IAQ(5P48H) Profile (Figure 6) is observed in that they both respond instantaneously to the "on" and "off" functions and normal operation of the air-conditioning systems.

Example 3. IAQ Profiles of the General Office of an Insurance Company in A Commercial Building in Causeway Bay, Hong Kong (Figures 8, 9 & 10).

Four units of YES205 Air Quality Monitors were placed at selected locations (as marked on the layout plan in Figure 8) to monitor independently and simultaneously the levels of five Primary Parameters of IAQ in an open office (occupancy: 100) located on the 33rd floor of a commercial building in Causeway Bay district of Hong Kong. The IAQ(5P48H) Profiles recorded are shown in Figure 9.

Concurrently, two units of PPM Formaldemeter operating in parallel were used to obtain IAQ(1P8H) Profiles of the same office. The IAQ(1P48H) Profile on formaldehyde and the statistical figures shown in Figure 9 are obtained by combining six consecutive runs of IAQ(1P8H) Profiles. The IAQ Profiles of this office have demonstrated that every air-conditioned premises has its own IAQ Profile characteristics. For the premises of this example, the characteristics may be summarized as follows:-

1. The temperature curves of all four IAQ(5P2D) Profiles indicate that the office air-conditioning system is turned on daily at 7:30 a.m. and turned off at 7:00 p.m. Good thermostatic control maintains consistent room temperatures with slight zonal variations, i.e., 24oC at survey points (A) & (D), 23oC at survey point (E) and 22oC at survey point (C), and consistent room temperature is achieved between two days at all four measurement points.

2. RH of the office is quite consistently maintained at the 60% level, which is normal for a well-maintained air-conditioned office of this size.

3. Carbon dioxide concentration is directly related to population density as well as ventilation rate. Although there are always zonal variations in an office of this size, in the morning, overall CO_2 level stays within the recommended good air quality level of 800 ppm at all four measurement points. On occasions, CO_2 level has exceeded 800 ppm in the afternoon. In the evening, high CO_2 level is due to the presence of the staff members and inadequate ventilation after the air conditioning system is turned off at 7:00 p.m.

4. The levels of both CO and NO_2 stay closely to the baseline throughout both days and at all four measurement points. This is normal for air-conditioned premises locating at high elevations such as this one on the 33rd floor.

5. The formaldehyde level as shown by the IAQ(1P48H) Profiles of Figure 9 remains at an acceptable level of around 50 ppb during office hours. The level starts to rise after the air conditioning system (i.e. ventilation) is turned off at 7:00 p.m. on both days and the level continues to rise until it reaches an equilibrium level of 200 to 250 ppb after midnight.

6. The transient dip of formaldehyde level happening around 23:00 hour on June 20th corresponds well with slight dipping of the temperature, RH and CO2 levels at the same time, which are shown by the curves of all four IAQ(5P48H) Profiles. This is another illustration of IAQ Profiles responding to management and usage of space.

CONCLUSIONS

1. The term "IAQ Profile" is defined, enabling it to be used correctly and accurately in communication.

2. Using state-of-the-art gas sensing, automatic sampling, data logging, digital technology and information technology, IAQ profiling can be accurate, efficient and cost effective.

3. The PPM Formaldemeter used in this work is designed for the H.K. Government to monitor airborne formaldehyde with high precision and accuracy at the concentration level of below 400 ppb as directed by the Government's Guidance Notes of IAQ Management.

4. The YES205 Air Quality Monitor used in this work is an ultra-compact field instrument with data logging and IAQ Profiling capabilities designed and built for the H.K. Government to monitor 5 Primary Parameters simultaneously for routine monitoring of indoor air quality.

5. Visual presentation of air-quality with IAQ Profile enables the dynamics of changing concentration levels of selected IAQ parameters over a specific period of time to be used in building management and in IAQ legislation.

6. Field studies on the applications of IAQ Profile have shown that every indoor environment controlled with air-conditioning and mechanical ventilation systems has its own unique and specific IAQ profiles which are affected by variables such as usage of the space, management of the building as well as design, condition and operation of the air-conditioning system.

7. Human bias and manipulations are completely eliminated in IAQ Profiling by automation in air quality monitoring, data logging, profiling as well as computing and presentation of the IAQ statistics. Complete automation can also be applied to the transmission of IAQ Profiles and data for assessment and storage, building management and IAQ control.

8. Strong recommendation is for the legislative bodies of Hong Kong and the other legislative bodies of the world to establish future laws and regulations of IAQ based of IAQ Profiles as a standard instead of based on single point measurements and their averages of the present practice.

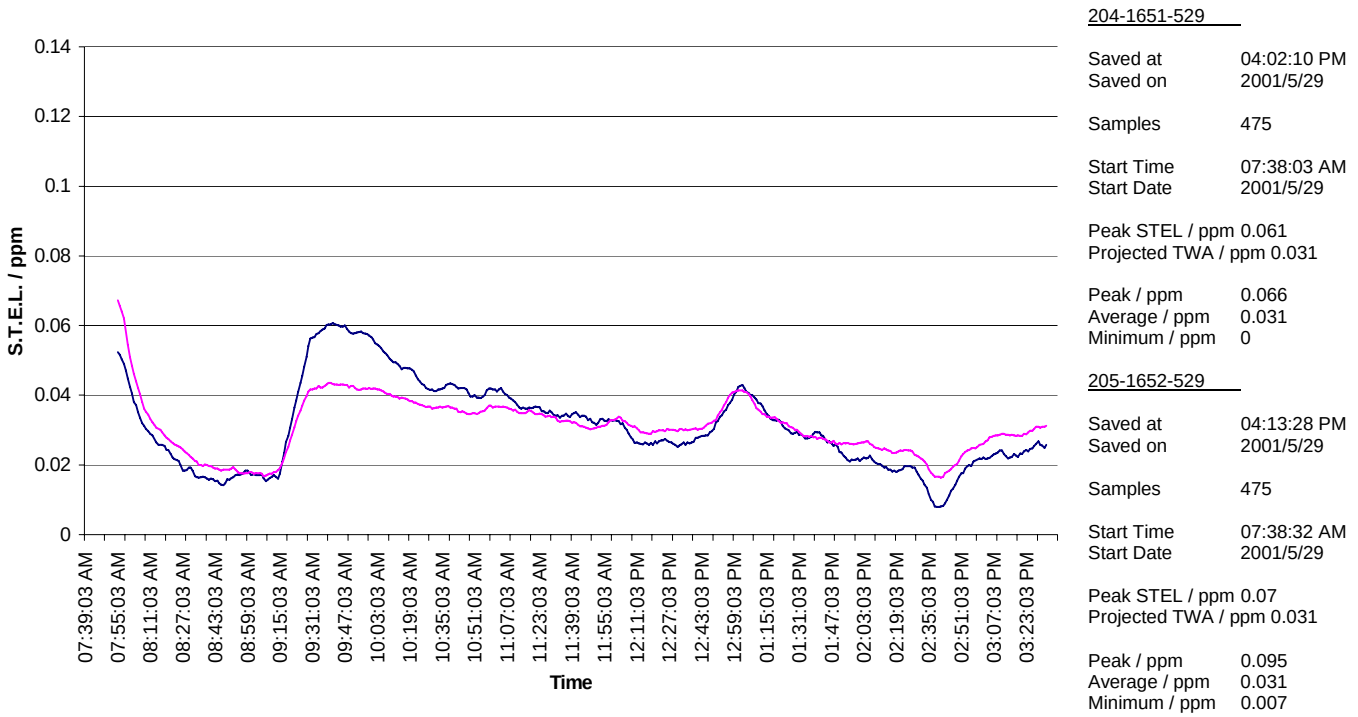
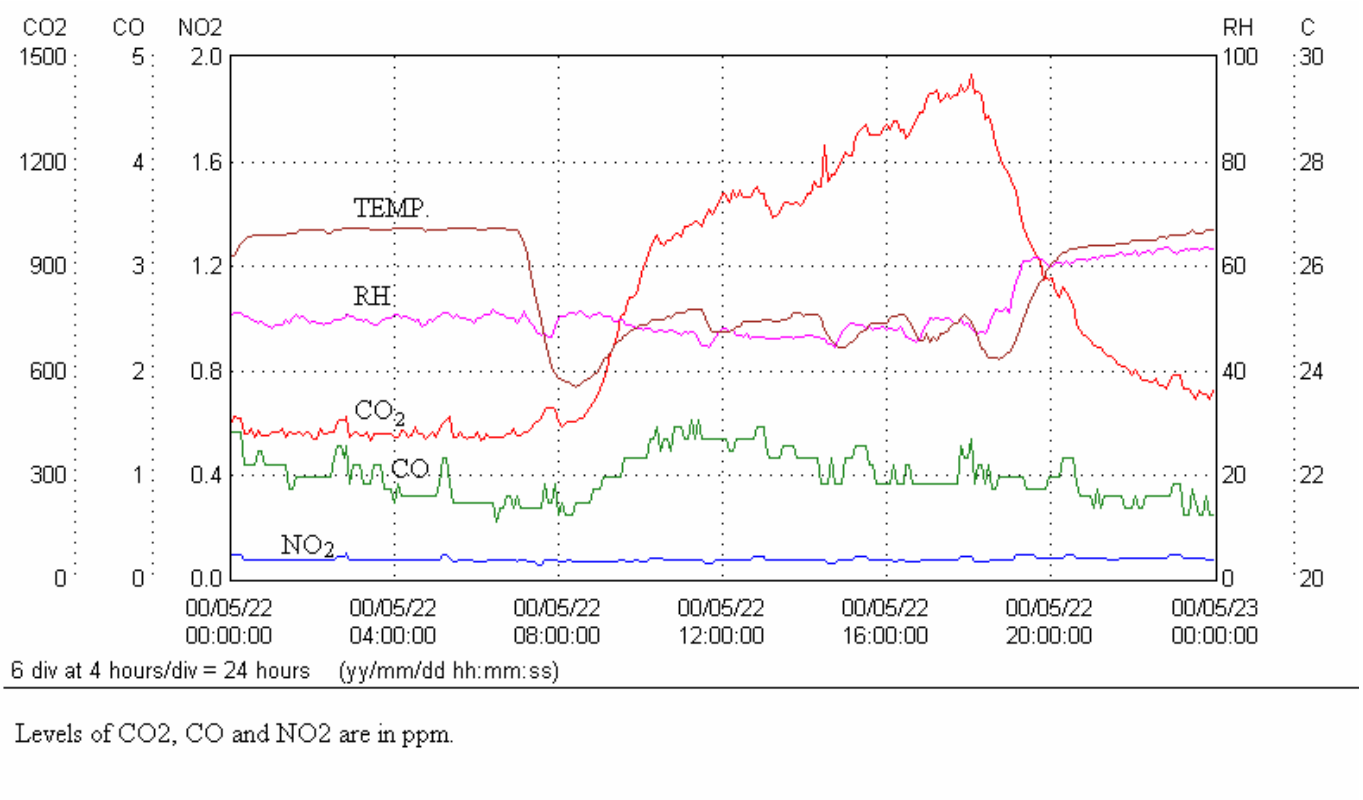


Figure 1 - IAQ(1P, 8H) Profiles on Formaldehyde and Profile Statistics of An Office by Two Units of PPM Formaldemeter



Levels of CO2, CO and NO2 are in ppm.

Figure 2 – An IAQ(5P, 24H) Profile of An Architect's Office

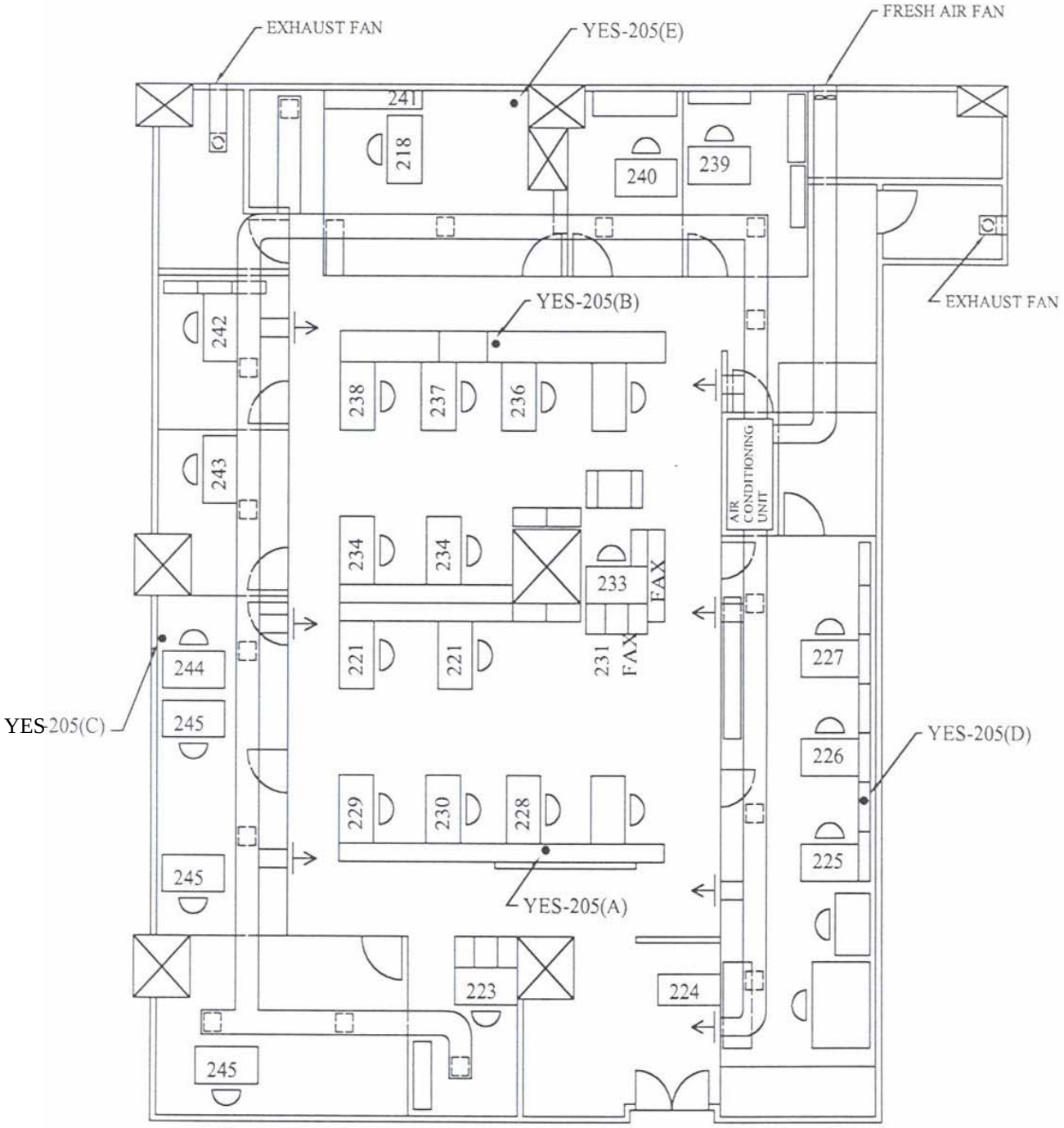
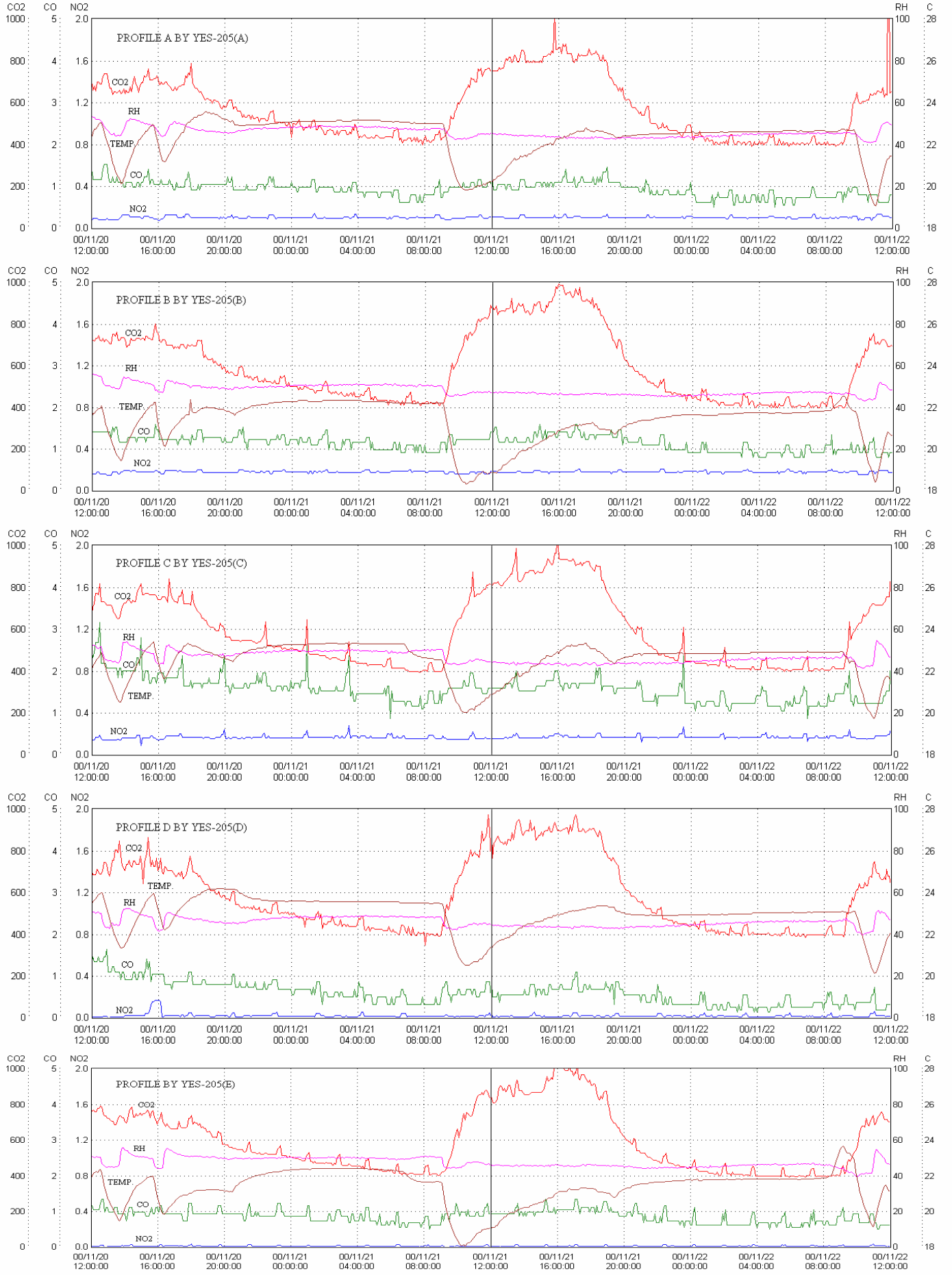


Figure 3 - Layout Plan of An Engineering Office



Levels of CO2, CO and NO2 are in ppm.

Figure 4 - IAQ (5P, 48H) Profiles of An Engineering Office

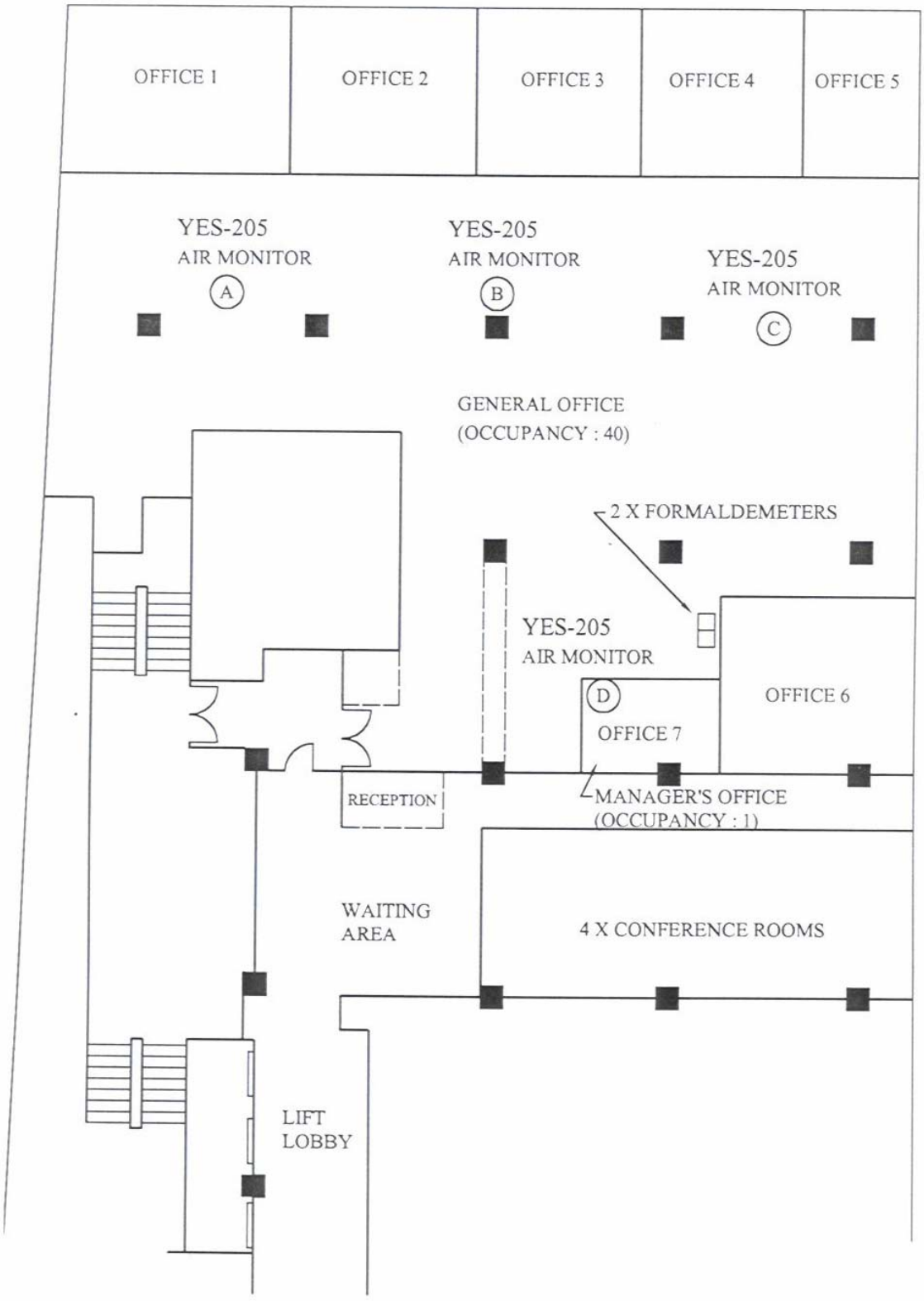
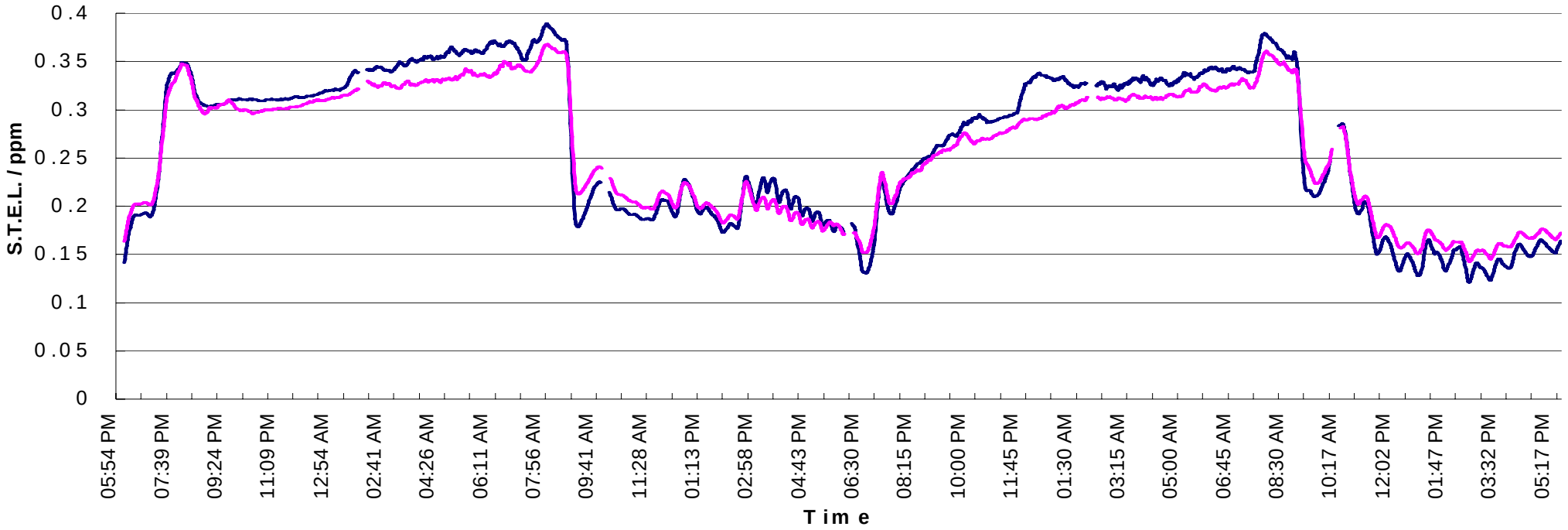


Figure 5 - Layout Plan of An Account's Office

Levels of CO2, CO and NO2 are in ppm.

Figure 6 - IAQ (5P, 48H) Profiles of An Accountant's Office

Figure 7 – IAQ(1P, 48H) Profiles on Formaldehyde and Profile Statistics of an Accountant's Office by Two Units of PPM Formaldemeter



204-1651-w5291		204-1651-w5301		204-1651-w5302		204-1651-w5303		204-1651-w5311		204-1651-w5312	
Samples	480	Samples	480	Samples	480	Samples	480	Samples	480	Samples	456
Start Time	05:53:34 PM	Start Time	01:55:53 AM	Start Time	09:57:44 AM	Start Time	05:59:43 PM	Start Time	02:02:28 AM	Start Time	10:04:57 AM
Start Date	2001/5/29	Start Date	2001/5/30	Start Date	2001/5/30	Start Date	2001/5/30	Start Date	2001/5/31	Start Date	2001/5/31
Peak STEL / ppm	0.349	Peak STEL / ppm	0.389	Peak STEL / ppm	0.231	Peak STEL / ppm	0.338	Peak STEL / ppm	0.379	Peak STEL / ppm	0.286
Projected TWA / ppm	2.95	Projected TWA / ppm	3.38	Projected TWA / ppm	1.99	Projected TWA / ppm	2.69	Projected TWA / ppm	3.24	Projected TWA / ppm	1.62
Peak / ppm	0.357	Peak / ppm	0.407	Peak / ppm	0.26	Peak / ppm	0.352	Peak / ppm	0.398	Peak / ppm	0.301
Average / ppm	0.294	Average / ppm	0.337	Average / ppm	0.198	Average / ppm	0.268	Average / ppm	0.323	Average / ppm	0.16
Minimum / ppm	0.117	Minimum / ppm	0.172	Minimum / ppm	0.163	Minimum / ppm	0.128	Minimum / ppm	0.204	Minimum / ppm	0.109

205-1652-w5291		205-1652-w5301		205-1652-w5302		205-1652-w5302		205-1652-w5311		205-1652-w5312	
Samples	480	Samples	480	Samples	480	Samples	480	Samples	480	Samples	454
Start Time	05:53:34 PM	Start Time	01:56:18 AM	Start Time	09:59:33 AM	Start Time	06:02:18 PM	Start Time	02:05:03 AM	Start Time	10:07:45 AM
Start Date	2001/5/29	Start Date	2001/5/30	Start Date	2001/5/30	Start Date	2001/5/30	Start Date	2001/5/31	Start Date	2001/5/31
Peak STEL / ppm	0.347	Peak STEL / ppm	0.368	Peak STEL / ppm	0.233	Peak STEL / ppm	0.313	Peak STEL / ppm	0.361	Peak STEL / ppm	0.283
Projected TWA / ppm	2.9	Projected TWA / ppm	3.23	Projected TWA / ppm	1.99	Projected TWA / ppm	2.57	Projected TWA / ppm	3.13	Projected TWA / ppm	1.75
Peak / ppm	0.352	Peak / ppm	0.381	Peak / ppm	0.245	Peak / ppm	0.33	Peak / ppm	0.382	Peak / ppm	0.292
Average / ppm	0.289	Average / ppm	0.322	Average / ppm	0.198	Average / ppm	0.256	Average / ppm	0.311	Average / ppm	0.174
Minimum / ppm	0.145	Minimum / ppm	0.208	Minimum / ppm	0.162	Minimum / ppm	0.149	Minimum / ppm	0.222	Minimum / ppm	0.134

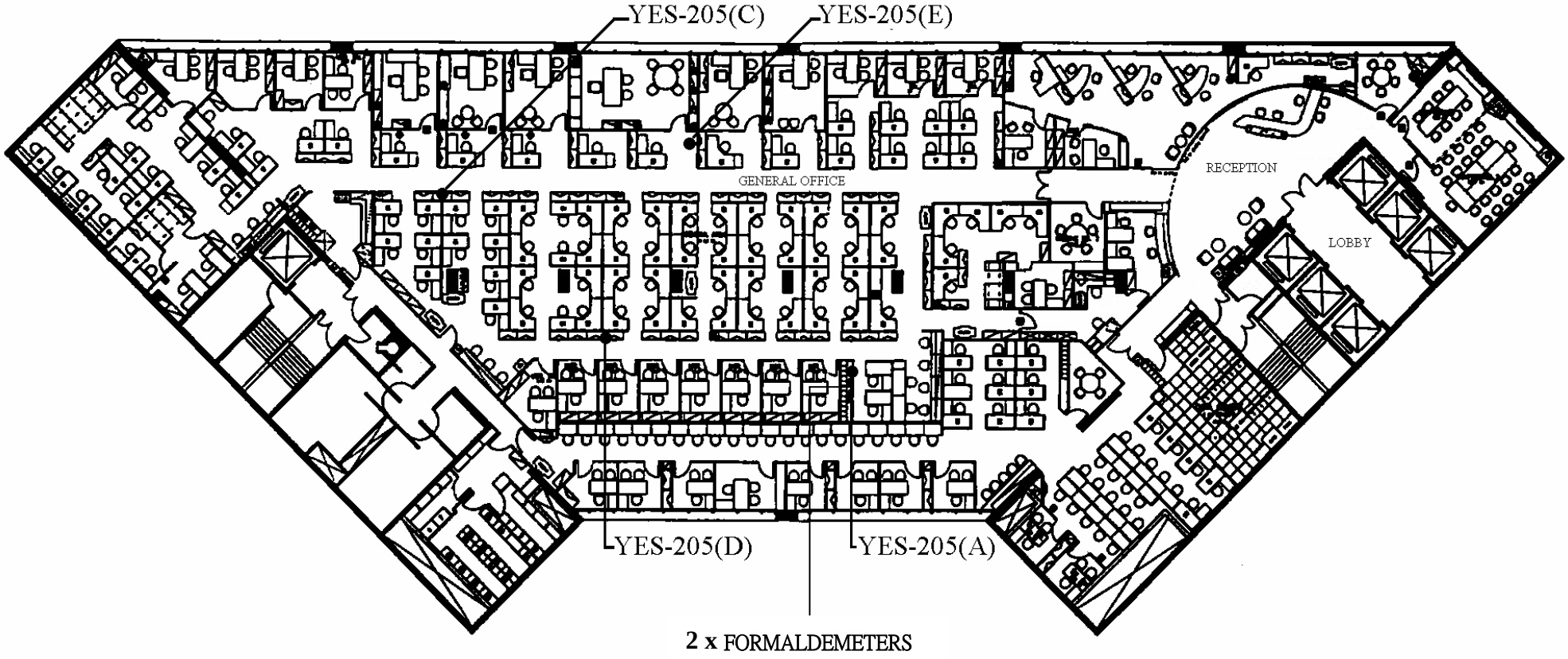
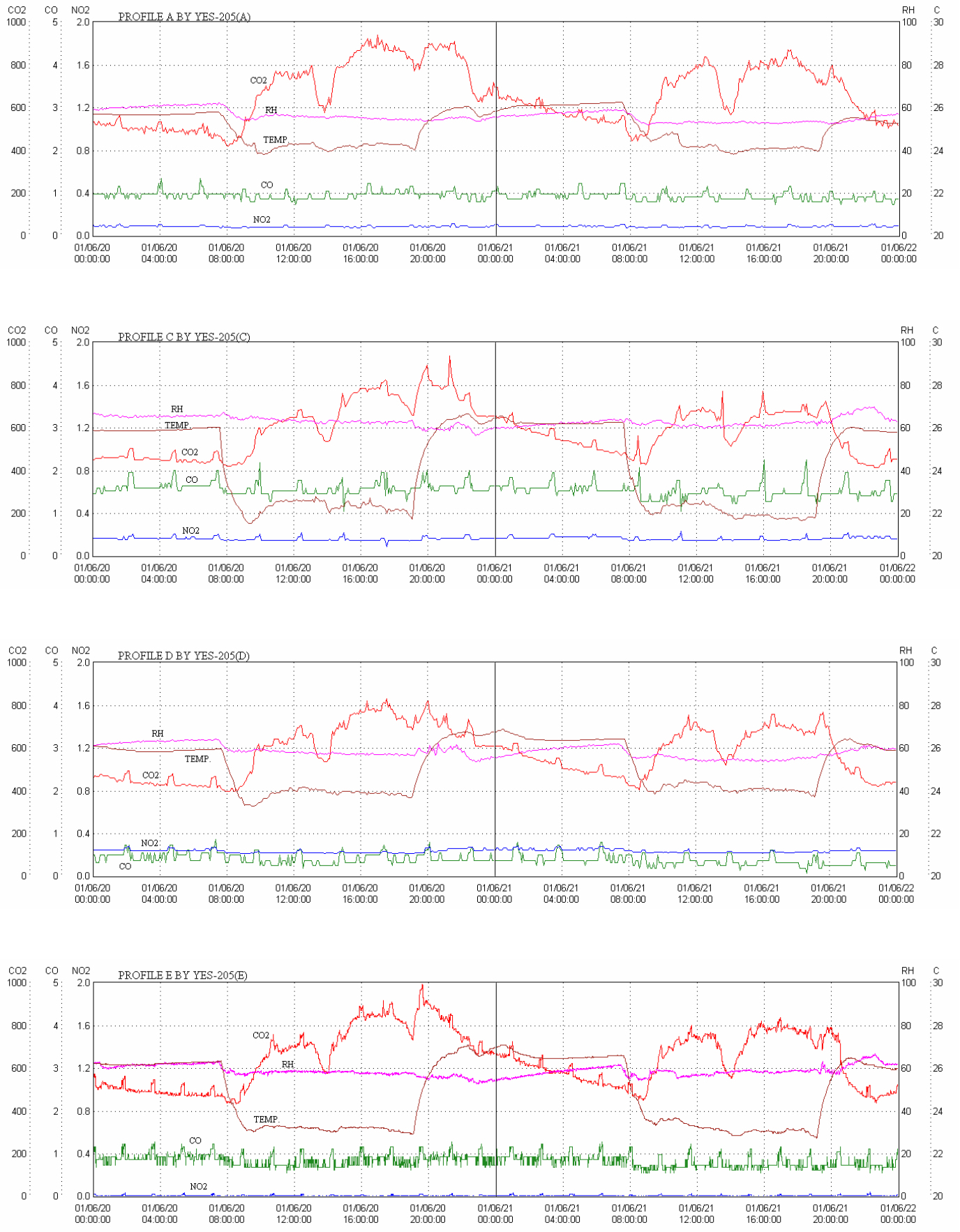


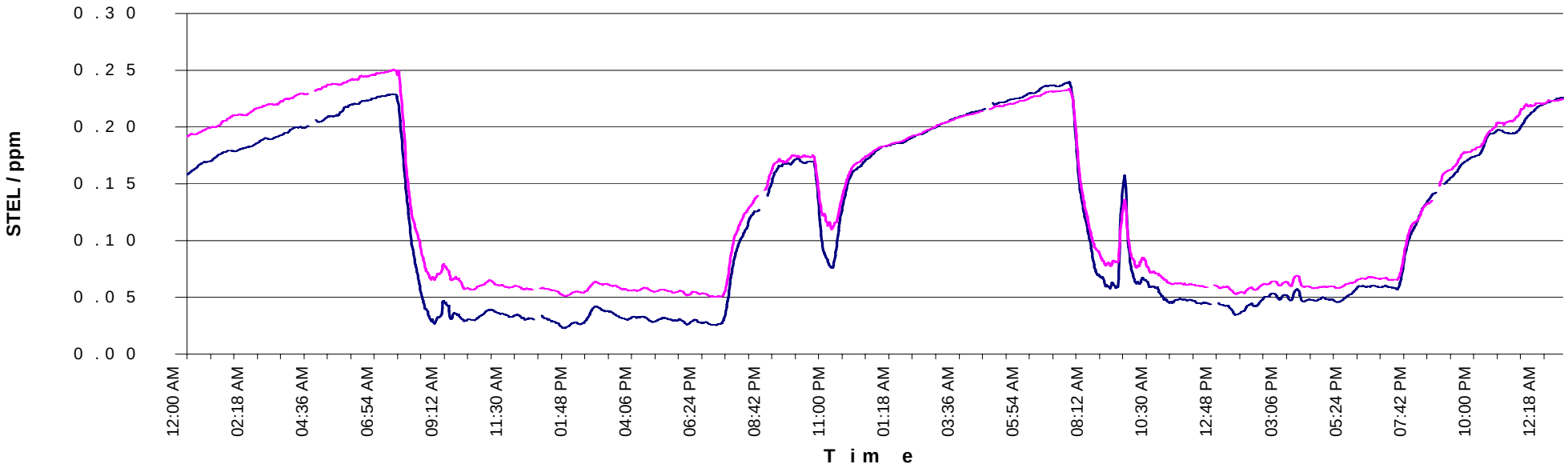
Figure 8 – Layout Plan of the General Office of an Insurance Company



Levels of CO2, CO and NO2 are in ppm.

Figure 9 – IAQ(5P, 48H) Profiles of An Insurance Company

Figure 10 – IAQ(1P, 48H) Profiles on Formaldehyde and Profile Statistics of An Office by Two Units of PPM Formaldemeter



204-1651		204-1651		204-1651		204-1651		204-1651		204-1651		204-1651	
Samples	480	Samples	480	Samples	480	Samples	480	Samples	480	Samples	480	Samples	480
Start Time	08:19:47 PM	Start Time	04:21:46 AM	Start Time	12:23:44 PM	Start Time	08:25:42 PM	Start Time	04:27:39 AM	Start Time	12:29:52 PM	Start Time	08:31:49 PM
Start Date	2001/6/19	Start Date	2001/6/20	Start Date	2001/6/20	Start Date	2001/6/20	Start Date	2001/6/21	Start Date	2001/6/21	Start Date	2001/6/21
Peak STEL / ppm	0.201	Peak STEL / ppm	0.229	Peak STEL / ppm	0.127	Peak STEL / ppm	0.216	Peak STEL / ppm	0.24	Peak STEL / ppm	0.142	Peak STEL / ppm	0.245
Projected TWA/ppm	0.155	Projected TWA/ppm	0.113	Projected TWA / ppm	0.042	Projected TWA / ppm	0.173	Projected TWA / ppm	0.131	Projected TWA / ppm	0.062	Projected TWA / ppm	0.211
Maximum / ppm	0.207	Maximum / ppm	0.233	Maximum / ppm	0.134	Maximum / ppm	0.22	Maximum / ppm	0.243	Maximum / ppm	0.146	Maximum / ppm	0.248
Average / ppm	0.155	Average / ppm	0.113	Average / ppm	0.042	Average / ppm	0.173	Average / ppm	0.131	Average / ppm	0.062	Average / ppm	0.211
Minimum / ppm	0.077	Minimum / ppm	0.012	Minimum / ppm	0.019	Minimum / ppm	0.068	Minimum / ppm	0.039	Minimum / ppm	0.031	Minimum / ppm	0.144
205-1652		205-1652		205-1652		205-1652		204-1652		205-1652		205-1652	
Samples	480	Samples	480	Samples	480	Samples	480	Samples	480	Samples	480	Samples	480
Start Time	08:18:17 PM	Start Time	04:18:49 AM	Start Time	12:19:21 PM	Start Time	08:19:52 PM	Start Time	04:20:22 AM	Start Time	12:20:54 PM	Start Time	08:21:24 PM
Start Date	2001/6/19	Start Date	2001/6/20	Start Date	2001/6/20	Start Date	2001/6/20	Start Date	2001/6/21	Start Date	2001/6/21	Start Date	2001/6/21
Peak STEL / ppm	0.23	Peak STEL / ppm	0.251	Peak STEL / ppm	0.14	Peak STEL / ppm	0.214	Peak STEL / ppm	0.234	Peak STEL / ppm	0.135	Peak STEL / ppm	0.239
Projected TWA/ppm	0.186	Projected TWA/ppm	0.142	Projected TWA / ppm	0.065	Projected TWA / ppm	0.177	Projected TWA / ppm	0.14	Projected TWA / ppm	0.07	Projected TWA / ppm	0.211
Maximum / ppm	0.235	Maximum / ppm	0.309	Maximum / ppm	0.148	Maximum / ppm	0.216	Maximum / ppm	0.247	Maximum / ppm	0.142	Maximum / ppm	0.245
Average / ppm	0.186	Average / ppm	0.142	Average / ppm	0.065	Average / ppm	0.177	Average / ppm	0.14	Average / ppm	0.07	Average / ppm	0.211
Minimum / ppm	0.103	Minimum / ppm	0.046	Minimum / ppm	0.046	Minimum / ppm	0.087	Minimum / ppm	0.054	Minimum / ppm	0.05	Minimum / ppm	0.136