Analysis and Statistics in Dealing with Environmental Engineering Issues Concerning Indoor Air, Volatile Organic Compounds in Science Park, and Chemical Mechanical Polishing Wastewater Treatment
博碩士論文電子檔案上網授權書

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論文題目：Analysis and Statistics in Dealing with Environmental Engineering Issues Concerning Indoor Air, Volatile Organic Compounds in Science Park, and Chemical Mechanical Polishing Wastewater Treatment

指導教授：黃思馨

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授權人：陳詩澄

簽 名：陳詩澄

中華民國 96 年 02 月 13 日
博碩士論文電子檔案上網授權書

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土木與工程資訊學系環境工程組
碩士班陳詩濤君所提之論文

Analysis and Statistics in Dealing with Environmental Engineering Issues Concerning Indoor Air, Volatile Organic Compounds in Science Park, and Chemical Mechanical Polishing Wastewater Treatment

，係由本人指導撰述，同意提付審查。

指導教授 ___________________（簽章）

中華民國 九十六 年 二 月
Preface

Environmental engineering is a diverse discipline burgeoning in Civil Engineering. The vigorous essence of environmental engineering is also furnished with various topics of researches and studies. In these three theses, different analysis and statistics methods are applied respectively, each thesis is written in a specific format to be adapted according to its purpose.

Among the knowledge areas in environment, issues involving fluid are the most fascinating, in particular indoor air and ventilation. In “Indoor Air Quality at Taipei Hospital with Indoor CO\textsubscript{2} concentration”, understanding how the factors influence the environment and CO\textsubscript{2} concentration in medical buildings is the first priority. Taipei Hospital is one of the major medical organizations in Taiwan. Second, to identify the factors considered during the review procedure using questionnaires and interviewing Taipei Hospital employees. This process introduces environmental issues such as estimating and statistics to develop a relationship between indoor environment, indoor air pollution and employees’ point of view. The results are also brought to attention, a proportionate relationship between indoor environment, air quality and employee performance. It also helps to speculate how to do the best control from an environmental engineer’s
perspective.

In addition to indoor air quality research, another research project focuses on the variation tendency of the volatile organic compounds existing in the Hsinchu Science Park environment. A model is proposed basing on Principal Component Analysis (PCA) theory and computer simulation with MATLAB software to sort and to analyze the concentration of volatile organic compounds and the sampling sites. In addition, the correlation of contaminants between residential district and the Science Park was taken into consideration. This may systematically and logically enhance the representability of the distribution of the volatile organic compounds in this period of time. This experience leads to the examination of the possible alternative methods for authorities concerned to review estimates, regulations and approaches for determining the feasibility of pollution prevention laws.

The third thesis is about chemical mechanical polishing (CMP) wastewater which mainly comes from the CMP process and post CMP cleaning. The composition of CMP wastewater is very complicated, and contains a high concentration of abrasive particles. This research probes into the treatment of chemical mechanical polishing (CMP) wastewater and BG wastewater from semiconductor factories.
These environmental-related research topics will likely be elucidated by combining conventional philosophy with modern methodologies, such as computer simulation techniques. These methodologies facilitate analyses previously deemed impossible.
Acknowledgements

Thanks to professor Sz-Chwun John Huang, professor Tseng-Hsing Hsu, professor Whei-Meih Chang and Dr. Yun-Hui Lin for giving me the opportunity to do such an amazing project, for guiding me, and for great leadership and support, and to lab mates, Yi-Han Lu, Yi-Chieh Wen, Chia-Ju Tsai, Hsin-Hua Chen, Pei-Chin Yu, Kuan-Yun Hou, Kuo-Shu Huang, Shin-Yi He, Zheng-Jyin Luo and Tai-Sheng Wang for a lot of help.
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Indoor Air Quality at Taipei Hospital with Indoor

CO₂ Concentration

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Abstract

The environment and concentration of CO$_2$ in a medical building was measured and compared with previous years' records to determine factors influencing the environment and CO$_2$ concentration in medical buildings. An employee survey was conducted in this hospital and combined with environment and CO$_2$ concentration statistics to develop a relationship between indoor environment, indoor air pollution and employees' point of view. The results also brought to attention, a proportionate relationship between indoor environment, air quality and employee performance.
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1. Introduction

In this essay, the CO$_2$ concentration in a medical building was investigated, with particular attentions paid to employee performance and working environment which were a great concern. This study will demonstrate how and what are the factors that critically affect indoor air conditions in a real environment and which of these should be paid attention to in medical buildings.

Indoor air quality (IAQ)

Indoor air quality (IAQ) concerning interior air that could affect health and comfort of building occupants, and has become an increasingly important issue, especially after the introduction of hermetically sealed modern buildings. IAQ could be compromised by chemicals (carbon monoxide, carbon dioxide, radon, etc.), microbial contaminants (bacteria, mold), allergens, and other mass that can induce health disorder. Studies have revealed that indoor air quality (IAQ) in sealed buildings, including homes, offices and other buildings, could be worse than that of outdoor. However, this has not become a common understanding of air pollution. Indoor air, in fact, is often a greater factor that causes health hazard than corresponding outdoor setting. Around 40% of male office workers and 60% female office workers who work in these kinds of buildings suffer from at least one of the Sick Building Syndrome (SBS), which is related to unhealthy building environment. [Jan Sundell, 1995] [1]. SBS symptoms could include headache, lethargy, fatigue, asthma, eyestrain and itch, snivel, dry throat, skin itch, nausea, and other symptoms [Max O. Bachmann, 1995] [2]. And after leaving these buildings, those symptoms could be improved or disappear.
The primary methods for air quality improvement in most buildings are using ventilation to dilute contaminants, filtration and source control. The efficiency of ventilation system, including supply and exhaust of the air flow, plays an important role in air quality control [S. Holmberg et al., 2003] [3]. The level of ambient CO₂ in indoor air is a key factor in determining its quality, and is often an indicator of insufficient ventilation. IAQ analyzing techniques include air samples collection, building surfaces samples collection and computer modeling of air flow inside buildings. The result can be applied in analyzing of bacteria, mold, chemicals, and other stressors. These investigations can lead to a better understanding of the sources of contaminants and eventually leads to strategies for removing unwanted elements from indoor air.

Carbon dioxide

Carbon dioxide is the main indoor pollutant that may cause occupants to get headaches, grow drowsy, and may lower activity levels of the occupants. Total indoor CO₂ must be reduced to below 600 ppm to eliminate most indoor air quality complaints. ASHRAE recommends that CO₂ concentration indoor not exceed 700 ppm above outdoor ambient levels. NIOSH considers that indoor CO₂ concentration exceed 1,000 ppm marks an inadequate ventilation level. The UK standards for schools indicates that CO₂ concentration, when measured at seated head height and averaged over the whole day, in all teaching and learning spaces, should not exceed 1,500 ppm. A whole day refers to normal school hours, 9:00 am to 3:30 pm, including unoccupied periods, such as lunch breaks. OSHA restricts CO₂ concentration in the workplace to 5,000 ppm for prolonged periods, and 35,000 ppm for 15 minutes. Canadian standards limit CO₂ concentration to 3,500 ppm.
Table 1. Health effects of respiratory exposure to carbon dioxide (Baxter, 2000 [4]; Faiivre-Pierret and Le Guern, 1983 [5]; NIOSH, 1981 [6]).

<table>
<thead>
<tr>
<th>Exposure limits (% in air)</th>
<th>Health Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-3</td>
<td>Unnoticed at rest, but on exertion there may be marked shortness of breath</td>
</tr>
<tr>
<td>3</td>
<td>Breathing becomes noticeably deeper and more frequent at rest</td>
</tr>
<tr>
<td>3-5</td>
<td>Breathing rhythm accelerates. Repeated exposure provokes headaches</td>
</tr>
<tr>
<td>5</td>
<td>Breathing becomes extremely laboured, headaches, sweating and bounding pulse</td>
</tr>
<tr>
<td>7.5</td>
<td>Rapid breathing, increased heart rate, headaches, sweating, dizziness, shortness of breath, muscular weakness, loss of mental abilities, drowsiness, and ringing in the ears</td>
</tr>
<tr>
<td>8-15</td>
<td>Headache, vertigo, vomiting, loss of consciousness and possibly death if the patient is not immediately given oxygen</td>
</tr>
<tr>
<td>10</td>
<td>Respiratory distress develops rapidly with loss of consciousness in 10-15 minutes</td>
</tr>
<tr>
<td>15</td>
<td>Lethal concentration, exposure to levels above this are intolerable</td>
</tr>
<tr>
<td>25+</td>
<td>Convulsions occur and rapid loss of consciousness ensues after a few breaths. Death will occur if level is maintained.</td>
</tr>
</tbody>
</table>

High carbon dioxide concentrations may limit the use of gas masks due to the lack of oxygen. Therefore, it has been recommended that when concentration exceed 1.5% by volume, the occupational short-term exposure limit value, the working or living areas should be evacuated immediately. Ambient guidelines for carbon dioxide do not exist. Occupational guidelines for carbon dioxide concentration are listed in the table.
Table 2. Occupational guidelines for CO₂

<table>
<thead>
<tr>
<th>Country/Institution</th>
<th>Level %</th>
<th>Level mg m⁻³</th>
<th>Averaging Period</th>
<th>Guideline Type</th>
<th>Date of Implementation</th>
<th>Relevant Law</th>
<th>Notes</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU</td>
<td>0.5</td>
<td>9000</td>
<td>8 hour TWA</td>
<td>OEL</td>
<td></td>
<td>Commission Directive 91/322</td>
<td>[7]</td>
<td></td>
</tr>
<tr>
<td>UK</td>
<td>1.5</td>
<td>274000</td>
<td>15 min</td>
<td>MEL</td>
<td></td>
<td>ILV</td>
<td>[8]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>9150</td>
<td>8 hour TWA</td>
<td>MEL</td>
<td></td>
<td>ILV</td>
<td>[8]</td>
<td></td>
</tr>
<tr>
<td>USA</td>
<td>3</td>
<td>540000</td>
<td>15 min</td>
<td>STEL</td>
<td>2003</td>
<td>NIOSH [9]</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;0.5</td>
<td>9000</td>
<td>8 hour TWA</td>
<td>PEL</td>
<td></td>
<td>OSHA [10]</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>9000</td>
<td>10 hour TWA</td>
<td>REL</td>
<td>2003</td>
<td>NIOSH</td>
<td>[9]</td>
<td></td>
</tr>
</tbody>
</table>

1. ppm by volume at 25°C and 760 torr.

There is scarcely any environment monitoring and discussion of Indoor Air Quality (IAQ) in domestic medical buildings. This research focuses on the assessment of a long-term CO₂ monitoring in a hospital, in order to provide a reference for environment improvement in the future.

2. Materials and Methods

Understanding how the factors influence the environment and CO₂ concentration in medical buildings was the first priority. Taipei Hospital is one of the major medical organizations in Taiwan. Second, factors considered were identified during the review procedure using questionnaires and interviewing Taipei Hospital employees.
Indoor CO\textsubscript{2} sampling methods

In order to obtain CO\textsubscript{2} variation situation during a day, a week, a month and a year, and CO\textsubscript{2} variation situation during working hours, non-working hours and holidays, 24-hour samplings at fixed locations and fixed time of each day is applied to monitor the concentration of CO\textsubscript{2}. Sampling sites includes from the 11\textsuperscript{th} floor to the basement 1\textsuperscript{st} floor in Taipei Hospital. There is one sampling site on each floor, and twelve in total. In addition to CO\textsubscript{2} concentration, temperature, relative humidity, occupants per space, square measure, the number and air flow volume of the supply and exhaust drafts of the ventilation system are taken into this survey. To avoid hinder hospital employees from operating, sampling equipments are placed at locations away from the wall, ventilation drafts, medical equipments, plant pots and other objects that might affect the result. Sampling equipments are located at sites which are representative of the space, at the height of 125cm-135cm. Monitoring machine sends a signal to digital recorder every 15 minutes. To establish a reference basis of the discussion of the relationship between the number of inhabitants, the size of the room, and CO\textsubscript{2} concentration, the number of inhabitants is also counted every hour and averaged.

A monitor with proper reacting time is required for some monitors are designed for continuous data collecting and demand more time for adjusting before operation[NIOSH Manual of Analytical Methods 6603; OSHA Analytical Method Manual] [11]. Telaire 7001 U.S.A with NDIR is used to measure CO\textsubscript{2} concentration, temperature, relative humidity. Digital recorder is Box-Car Version 3.7+ for windows. Anemograph is Kanomax 24-6111 Japan, which is thermo-sensing, and its measuring range is 0-50m/s, with $\pm2\%$ inaccuracy.
Outdoor CO$_2$ sampling methods

Outdoor air could come into the indoor environment by means of natural or machinery ventilation, and changes indoor air quality to a certain level. In this study, outdoor CO$_2$ concentration is detected to analyze its influence on the variation of indoor CO$_2$ concentration.

Sampling time is 10:00 and 15:00, at a pinpoint at the front gate of the hospital every day, including weekends and holidays. Samples are taken at the height between 130cm and 145cm. After equipment is warmed up for 5 minutes, measurement starts and continues collecting data for 10 minutes, acquiring the maximum, minimum and average values. Wind speed, temperature, and humidity data at the location are obtained from the Central Weather Bureau.

Testo 535 is used to detect CO$_2$ concentration, 2 channel infrared absorption principal is applied. Measuring range is 0ppm to 9999ppm CO$_2$, accuracy is 0ppm to 5000ppm ±50ppm +2% of m.v, 5000ppm to 9999ppm ±100ppm +3% of m.v. Resolution is 1ppm or 0.001 vol. %.

Equipments are adjusted according to standard procedure or auto-adjusted before sampling to meet the QA/QC requirement.

Inquiry survey

A survey was conducted on hospital employees to find out what should be paid attention to when managing a hospital.

Interviewees are from a hospital, and in order to have a clearer understanding of the hospital and employees, questionnaires were widely distributed to employees of various
professions to avoid being too conservative or too restricting. All the questioned employees are experts in certain medical technology fields.

This inquiry aimed to investigate the environment-related issues of this hospital through questioning how employees felt about the sanitation, air quality, air conditioning, odor, temperature, humidity, noise, ventilation, dust, smoke and other concerned factors. The aforementioned are integrated to be the satisfactory degree toward the working environment according to interviewees' daily experience.

Reference materials are questionnaires designed by NIOSH, "NIOSH Indoor Air Quality and Work Environment Symptoms Survey" [NIOSH Indoor Air Quality and Work Environment Symptoms Survey, 1991] [12], and information on QuestionPro website [QuestionPro][13]. The contents of the questionnaire includes four employee categories of different "gender", "age", "education background" and "working floor", each status has four aspects of view toward the "sanitation", "air quality", "environment" and "personal health condition". The answers were categorized into five satisfaction levels, "Very Poor", "Unsatisfactory", "Neutral", "Satisfactory", "Superior".

The questionnaires were randomly distributed to the hospital employees. The statistics were compiled with the number of votes in favor of each choice.

3. Results and Discussion

3.1 Historical trends in indoor CO₂ concentration at Taipei Hospital

In this figure, there is an obvious change in 1996. The building is old, and before 1996, the early air conditioning system including pipes and equipment that didn’t function well, thus CO₂ could not be efficiently removed but accumulated in the environment. Therefore,
during that period, the CO$_2$ concentration was in violation of the ARHREA standards.

After 1996, when the air conditioning system was replaced, CO$_2$ concentrations met the requirement of Hong Kong standards.

Figure 1. The time course of indoor CO$_2$ concentration
3.2 Effect of environmental factors on indoor CO$_2$ concentration

3.2.1 Humidity

Humidity has been considered a main factor that could affect the concentration of CO$_2$ in the building since CO$_2$ dissolves in water in a comparatively high proportion than other airs. Data acquired in February are analyzed and illustrated in the following figure. The curve of CO$_2$ concentration approximately fluctuates oppositely to the curve of humidity. This inclination could indicate a puny inverse proportion correlation between CO$_2$ concentration and humidity in a chamber.

3.2.2 Temperature

Data of temperature in the same period are illustrated below. No tendency and obvious correlation between temperature and CO$_2$ concentration can be concluded according to the figure.

The slight correlation between humidity and CO$_2$ concentration, and the unconcerned relation between temperature and CO$_2$ concentration can be assumed that humidity and temperature are not dominant factors that affect the CO$_2$ concentration inside a building. Moreover, this inference also demonstrates the accuracy of this measurement that with minor influence from humidity and temperature which can be eliminated from a large-scale view.
Figure 2. Humidity, Temperature and CO₂ concentration in February
3.2.3 Daily variation of CO$_2$ concentrations

The following figures illustrate the average variation of CO$_2$ concentration on each floor during one day. On the basement and the 2$^{nd}$, 3$^{rd}$, 5$^{th}$ floors, the concentrations are higher during the daytime, and gradually decrease with time (Fig. 3.) At midnight and early morning, the CO$_2$ concentrations decline to the minimum amount. However, on the 1$^{st}$ and 10$^{th}$ floors, this trend is less obvious. On the 4$^{th}$, 6$^{th}$, 7$^{th}$, 8$^{th}$, 9$^{th}$, 11$^{th}$ floors, where the wards are located, there is scarcely any change or fluctuation in CO$_2$ concentrations (Fig. 4.)
Figure 3. Daily variation of CO$_2$ concentrations on the basement, 1$^{st}$, 2$^{nd}$, 3$^{rd}$, 5$^{th}$, and 10$^{th}$ floors.
Figure 4. Daily variation of CO₂ concentrations on the basement, 4th, 6th, 7th, 8th, 9th, 11th floors.
3.2.4 On-duty and off-duty hours

This figure shows the CO₂ concentration during working time and duty-off time on each floor (Fig. 5). The data shows that CO₂ concentrations are higher during working time and lower in duty-off time. This situation results from the difference in number of employees and patients during working time and duty-off time.

![Graph showing CO₂ concentrations on different floors during on-duty and off-duty hours.]

Figure 5. Variation of CO₂ concentrations during on-duty and off-duty hours
3.2.5 Floor: Lower and higher floors (weekend)

The first figure illustrates the CO₂ concentration and its range on each floor, and the second figure shows the CO₂ concentration average in weekdays and Sundays.

These two figures could be integrated to indicate that in lower floors, the CO₂ concentration differs from weekdays to Sundays, which is higher during weekdays (including Saturdays on which the hospital still conducts consulting and treatment as Monday to Friday), and lower on Sundays. However, on higher floors, where the wards are, there is no distinct CO₂ concentration, because there is scarcely change in the number of hospitalized patients.

Moreover, the lower floors are open spaces, and allow air to ventilate from outside, greatly reducing the CO₂ concentration, yet the basement has a higher CO₂ concentration due to its location and poor ventilation.
Figure 6. CO₂ concentration and its range on each floor; Average CO₂ concentration in weekdays and Sundays
3.2.6 Outdoor CO₂ Concentration Change

The following figures show the variation of outdoor CO₂ concentration in three different months, May, July and September. These fluctuating curves stay in a certain range in each month, 450-550ppmv in May with the mean value of 475ppmv, 475-625ppmv in July with the mean value of 525ppmv, and 475-575ppmv in September with the mean value of 500ppmv. However, if the CO₂ concentrations are compared monthly, the variation is apparent. In June, CO₂ concentration exceeds 600ppmv to the maximum value of the year, and the maximum mean value appears in July.
Figure 7. Variation of outdoor CO₂ concentration in May, July and September
Figure 8. Monthly variation of outdoor $\text{CO}_2$ concentration
3.2.7 Number of workers, air flow rate and size of working space

From the following chart and figures, it could be inferred that the density (workers/m²) is not an accurate index, because there are several factors other than density that influence the air quality.

However, in an independent environment, for example, on one floor, there is a high correlation between density and CO₂ concentration. This is revealed in the chart and the second figure, which presents the eighth floor as an example.

Meanwhile, regarding one floor as a whole, the number of workers is an essential factor. In the first figure, the CO₂ concentration – Number of workers figure demonstrates a saturated curve, in other words, when the number of workers increases, the CO₂ concentration rises to the maximum, a saturated value. In an environment that CO₂ concentration accumulates to the saturated value, people should feel uncomfortable; however, most people are unaware of this change.

<table>
<thead>
<tr>
<th>Floor</th>
<th>Average [CO₂], ppm</th>
<th>Average density workers/m²</th>
<th>Slope</th>
<th>Intercept</th>
<th>Correlation</th>
<th>Significance</th>
<th>No. of workers</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>769.8</td>
<td>6.00</td>
<td>0.16</td>
<td>0.037</td>
<td>157.8</td>
<td>745.0</td>
<td>0.911</td>
</tr>
<tr>
<td>1</td>
<td>718.0</td>
<td>10.75</td>
<td>0.03</td>
<td>0.010</td>
<td>972.0</td>
<td>691.0</td>
<td>0.929</td>
</tr>
<tr>
<td>2</td>
<td>757.6</td>
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<td>0.77</td>
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<td>755.1</td>
<td>0.971</td>
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The main source of carbon dioxide of a building is the occupants. Carbon dioxide is exhaled as a byproduct of living processes. It should be removed by efficient ventilation system, a faulty ventilation system could buildup the concentration of carbon dioxide and thus reduce the regular oxygen concentration. Carbon dioxide is not generally found at a hazardous level in an indoor environment, however, it is often measured to determine the indoor air quality of a building, because it is a representative measurement of how well the ventilation system is working in relation to the number of occupants. If the carbon dioxide level stays high, it could be assumed that the ventilation system doesn’t adequately remove indoor pollutants in the area and this in turn may allow for the buildup of other indoor pollutants. The Occupational Safety and Health Administration (OSHA) and the American Conference of Governmental Industrial Hygienists (ACGIH) have set workplace safety standards of 5,000 ppm as an 8-hour time weighted average (TLV-TWA) exposure. TLV-TWA is the average concentration to which most workers may be exposed repeatedly day after day, for a normal 8-hour workday, 40-hour workweek, without harmful effects. This standard is only proposed as a guide in industrial environment. The American Society of Heating Refrigerating and Air-conditioning Engineers (ASHRAE) recommends that indoor carbon dioxide concentration no more than 700 ppm above the outdoor ambient carbon dioxide concentration, in order to minimize human odours and to maintain comfort. The ASHRAE 62-1989 recommends a minimum ventilation rate, the outdoor intake, of 15 cubic feet per minute per person. In offices, the recommended ventilation is 20 cubic feet per minute per person.
Figure 9. CO₂ concentration - number of workers, for B1-11F; CO₂ concentration - number of workers, for 8F
3.3 Questionnaires

According to the survey, the results are concluded into four categories: gender, age, education background and floor, each status has four views towards sanitation, air quality, environment and personal health condition. The questions are set into five satisfaction levels, which are “Very Poor”, “Unsatisfactory”, “Neutral”, “Satisfactory”, “Superior”. Chi-Square Test is applied to examine the correlation in each category. Three of the categories, analysis of age toward personal health condition, analysis of educational background toward workplace air quality, and analysis of working floor toward workplace air quality, are shown as follow.
3.3.1 Chi-Square Test

Analysis of age toward personal health condition:

According to the survey, the level of satisfaction towards personal health with respect to age is shown as follows:

![Bar chart showing satisfaction levels by age group.](chart.png)

Figure 10. Statistical chart of "age toward personal health condition"

Test of independence, $\alpha = 0.05$
Degree of freedom = 20
Critical value = 31.4
Chi-Square statistics = 35.18
Probability value = 0.00376

Chi-Square statistics = 35.18 > Critical value = 31.4
Probability value = 0.00376 < $\alpha = 0.05$
According to Chi-Square Test, personal health condition is correlative to age. In this figure, only employees over 60 years old selected “Superior”, but the major portion of 60 year-olds still chose “Neutral”. Meanwhile, “Very Poor” was chosen only by employees aged 30 to 39. Employees of other ages mainly chose between “Unsatisfactory” and “Satisfactory” levels. This situation reveals that employees over 60 show no negative feelings about their health condition, while those aged 30 to 39 show the worst feelings.
Analysis of educational background toward workplace air quality:

According to the survey, the level of satisfaction towards workplace air quality with respect to educational background is shown as follows:

Figure 11. Statistical chart of “educational background toward workplace air quality”

Test of independence, $\alpha = 0.05$
Degree of freedom = 20
Critical value = 31.4
Chi-Square statistics = 55.09
Probability value = 3.44E-06

Chi-Square statistics = 55.09 > Critical value = 31.4
Probability value = 3.44E-06 < $\alpha = 0.05$
According to Chi-Square Test, educational background is correlative to the employees’ view about workplace air quality. This figure shows that only employees with graduate school background feel the air quality is “Superior”, and also showed no negative feelings. Meanwhile, employees with junior college background have the worst impression of the air quality of their workplace.

Analysis of working floor toward workplace air quality:

According to the survey, the level of satisfaction towards workplace air quality with respect to working floor is shown as follows:

Figure 12. Statistical chart of “working floor toward workplace air quality”
Test of independence, $\alpha = 0.05$
Degree of freedom = 44
Critical value = 61.2
Chi-Square statistics = 66.59
Probability value = 0.0155

Chi-Square statistics = 66.59 > Critical value = 61.2
Probability value = 0.0155 < $\alpha = 0.05$

According to Chi-Square Test, the level of satisfaction towards workplace air quality is correlative to the employees’ working floors. From this figure, it can be concluded that the level of satisfaction varies according to which floor the interviewees work. It can be seen that up to 80% of employees on the 8th floor have chosen “Very Poor”, and 20% felt “Unsatisfactory”. Half of interviewees on the 3rd floor feel air quality is “Unsatisfactory” while 13% of employees on the 1st floor believed the air quality to be “Superior”.

3.3.2 The link between CO₂ concentrations and interviewees’ perspective on the air quality

The above statistics of “genders toward the sanitation, air quality, environment and personal health condition” indicates that males tend to be more satisfied with sanitation, air quality, environment and personal health. It is generally known that females have stricter criteria when judging the quality of their surroundings, while males get on easier with their environment, as proven in these analyses.

According to these “age toward the sanitation, air quality, environment and personal health condition” data and analysis, a conclusion could be made that older employees have a more positive view toward their workplace sanitation, air quality, environment and health condition of themselves. This trend could be related to that employees of older age mostly have a higher rank in the hospital based on the inquiry and observation. For example,
senior doctors, nurses and managers, whose offices are often located in quieter and cleaner sites of the hospital, and this leads to a cozier feeling of employees about the working environment and themselves.

The 1st floor of a hospital is a lobby, and where the administration center, registration office and medication claiming office are located. This floor is decorated and spacious with less disinfectant than the consulting rooms and in-patient rooms of other floors. Interviewees from the 1st floor have a more positive evaluation of the air quality. Besides, the lobby of the 1st floor is an open entrance, which makes it more efficient for indoor air to ventilate with air outside. Note that the employees on the 8th floor appeared to be obviously dissatisfied not only with workplace sanitation but also with air quality, which means this floor is the worst. This situation could be inferred from the specific function and quality of the 8th floor. This data analysis revealed the level of satisfaction with air quality differs not only by working floor, but also by the function and quality of the floor.

Stable average values between 700 to 800ppm of CO₂ concentration in each floor of a day and a week are found. The data shows merely slight differences of CO₂ concentration between floors. Comparing this result to the outcome of previous inquiry survey of the “working floor toward the workplace environment” which indicates a rare connection, a highly matching coincidence is reached.

However, when the CO₂ concentration is further discussed based on the “working floor toward the workplace air quality” inquiry result, a conclusion could be made that the satisfactory level acquired from the inquiry reveals scarcely little influence of the value of CO₂ concentration on the interviewees’ feelings of air quality. The most possible influential factor is that how interviewees evaluate the air quality of their workplace. The atmosphere in the building is colorless, therefore, most interviewees decided the satisfactory
level of air quality through smelling. Thus, the odor of the environment significantly determines the consequence of the inquiry.

4. conclusions

Previous research has demonstrated that most people spend 80-90% of time indoor, [Lebowitz M.D. et al., 1985] [14], poor air quality may cause discomfort and unhealthiness of human body, increase employee’s absence possibility, and reduce productivity. In this study, CO$_2$ is chosen from the six main categories of factors that influence the air quality [Yocom J.E., 1982] [15]. Combine monitor data with questionnaire analysis, it can be concluded that the concept of physical examination has a great effect on the outcome of this survey and leads to a misunderstanding of interviewees’ health condition and thus influences their answers.

Due to the limitation of the experimental equipments of this investigation, the CO$_2$ concentration is sampled at one site of each floor. Although all the values of each floor passed the ARHREA, which should be under 1000 ppm, the advanced research that if CO$_2$ concentration the critical factor that does great influence should be conducted. The sampling of CO$_2$ concentration at specific sites is recommended in the future survey, in order to have overall comprehension that whether the population and/ or medical instruments the element that produces more CO$_2$ at certain specific sites in each floor, and thus effects the impressions of interviewees toward air quality. Once the causes are confirmed, further qualitative investigations could be directed through more detailed inquiries to conclude the main decisive factors.
References


[10] OSHA Standards Website


Adjusting the Flow Rate of Return Settling Sludge
to Improve Treatment Efficiency of
CMP Wastewater

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Abstract

Chemical mechanical polishing (CMP) wastewater mainly comes from the CMP process and post CMP cleaning. The composition of CMP wastewater is very complicated, and contains a high concentration of abrasive particles.

This research probes into the treatment of chemical mechanical polishing (CMP) wastewater and BG wastewater from semiconductor factories. PAC and FSC-888 are applied for coagulation. The sludge after treatment was fed back into the original wastewater to determine the relationship between the various PAC or FSC-888 dosages and the turbidity of the upper layer wastewater after processing. The CMP wastewater characteristics and BG wastewater were tested before the experiment. The effect with and without the backflow sludge of different amounts was obtained.
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1. Introduction

Chemical mechanical polishing (CMP) wastewater and backside grinder (BG) wastewater come from semiconductor manufacturers. Both have a difficulty in sedimentation. However, the sludge could be of great use. This study is to investigate the influence of the bottom sludge adding in the first reaction tank when treating CMP wastewater and BG wastewater.

According to the differences mentioned above, CMP wastewater was mixed with the BG wastewater to destroy the stable state of the suspended particles of CMP wastewater by neutralization. Then the sludge of various quantities were taken out and added into the original wastewater to be treated. The NTU values of the wastewater after treatment were analyzed to figure out the relationship between backflow sludge rate and the NTU values.

2. Method

2.1 Experiment on treating CMP wastewater

This research mainly focused on if after PAC treatment, CMP sludge can be added into the original wastewater, the PAC dosage needed, and the NTU after treatment by adjusting the volume of sludge. The necessary checking of the essential quality of the CMP wastewater should be done first. According to the quality of wastewater, experiments are then conducted to find out the effect of different sludge volumes added.

2.1.1 Material

Ten percent of PAC is applied for treatment. Sulfuric acid is diluted to 6N for pH adjusting. Sodium hydroxide is diluted to 1N for pH adjusting. All above chemicals are
industrial grade.

The CMP wastewater of this experiment was sampled from a semiconductor manufacturer, that mainly produces 0.15 μm - 0.18 μm chips. This CMP wastewater is a mixture of Oxide waste liquid and its washing wastewater and Tungsten waste liquid and its wastewater. The samples are obtained by random sampling, including workdays and holidays. The pH and NTU values were immediately analyzed after sampling.

2.1.2 Analysis of original wastewater

In order to know the quality and basic components of wastewater, CMP wastewater was analyzed to check its pH, NTU and particle size distribution, to establish its background data.

2.1.3 Testing pH, PAC dosage, stirring speed, and standing duration

Six stirring tanks were prepared, each containing two liters of samples. PAC was added according to basic dosage suggestion in references. The pH values of six tanks were adjusted to 4, 5, 6, 7, 8 and 9 respectively. Wastewater samples were rapidly stirred for 3 minutes, slowly stirred for 20 minutes and left rest for 20 minutes before checking the turbidities of upper layer water of each tank. The best pH range was then controlled.

Two liters of original wastewater samples were put into six stirring tanks. The pH values were adjusted to the best pH value range according the above tests. Various dosages of PAC were then added to the stirring tanks. After rapid stirring for 3 minutes, slow stirring for 20 minutes and leaving rest for 20 minutes, the turbidities of upper layer water were examined to decide the best PAC dosage added.

Since the best pH and PAC dosage were found, the experiments were conducted to obtain the best stirring speeds. First, rapid stirring at 180 rpm, 190 rpm, 200 rpm, 210 rpm and 220
rpm. After deciding the best rapid stirring speed, slow stirring speeds were adjusted to 10, 20, 30, 40 and 50 rpm respectively. The wastewater samples were left stand for 20 minutes before testing the upper layer water turbidity.

The wastewater samples were controlled under the best pH, PAC dosage and stirring speed and then the turbidities were measured after leaving to stand for 5, 10, 15, 20, 25, 30, 35 and 40 minutes respectively. The best standing duration was thus determined.

Thus, CMP wastewater without CMP backflow sludge was examined to find out the best experimental pH condition, dosage of PAC, stirring speed and standing duration.

2.1.4 Treatment of CMP wastewater with and without backflow sludge

CMP wastewater with and without various CMP backflow sludge volumes were examined to find out the best experimental backflow sludge rate, pH condition, PAC dosage, turbidity and sludge standing duration.

The CMP wastewater was analyzed after treating to test the pH, NTU, and particle size distribution.

The experimental procedure could be illustrated as Fig. 2.1-1.

2.2 Experiment on treating CMP + BG wastewater

2.2.1 Material

Five percent FSC-888 was used instead of PAC, and three percent FSC-388 was added after rapid stirring. Other chemicals were the same as the above experiment on treating CMP wastewater.

The CMP and BG wastewater of this experiment was sampled from a semiconductor manufacture factory, which main products are 0.15 μm - 0.18 μm chips. This CMP
wastewater is the mixture of Oxide waste liquid and its washing wastewater and Tungsten waste liquid and its wastewater. The samples were obtained by random sampling on both workdays and holidays. The pH and NTU values were immediately analyzed after sampling.

2.2.2 Analysis of original CMP + BG wastewater

In order to know the quality and the basic components of wastewater, CMP wastewater, BG wastewater and CMP + BG wastewater was analyzed to check its pH, NTU and particle size distribution, and to establish its background data.

2.2.3 Testing on pH, FSC-888 dosage, stirring speed, standing duration

Testing procedure was the same as the CMP wastewater test except the FSC-888 of 400, 450, 500, 550, 600, 650ppm was applied instead of PAC, and an extra chemical of FAS-388 of 50, 100, 150, 200, 250, 300ppm was added after the stirring speed test.

Consequently, CMP + BG wastewater without CMP + BG backflow sludge was examined to find out the best experimental pH condition, the dosage of FSC-888, stirring speed and standing duration.

2.2.4 Treatment of CMP + BG wastewater with and without backflow sludge

CMP + BG wastewater with and without various CMP + BG backflow sludge volumes were examined to find out the best experimental backflow sludge rate, pH condition, the dosage of FSC-888, turbidity and sludge standing duration.

Analyze the CMP + BG wastewater after treating to test out the pH, NTU and particle size distribution.
The experiment procedure could be illustrated as Fig. 2.2-1.

3. Results and Discussion

3.1 Experiment on treating CMP wastewater

The wastewater was acquired from a semiconductor manufacturer factory in the Hsinchu Science Park. According to the results, the wastewater contained highly suspended particles which were well distributed in the water. To subside those particles, the first step is to break the stability of this condition, and thus make it possible to remove the solids in the wastewater. In this experiment, PAC was applied as coagulant to evaluate the influence of sludge backflow on the dosage of coagulant. Results of this experiment are as follow:

3.1.1 Data analysis

1. When CMP wastewater was treated with PAC, the best dosage was found to be 40 mg/L as Al₂O₃, which improved the clarity of the upper layer liquid and reduced the turbidity to a value of 4.5 NTU (Fig. 3.1-1). The pH value was controlled between 6.0 – 6.5 to yield the best results. The PAC dosage should be properly controlled because the PAC changes the pH value of the CMP wastewater. When a 30 mg/L as Al₂O₃ PAC dosage was added, and pH value stayed at 5.6 (Fig. 3.1-2), the turbidity could be reduced to 17.6 NTU (Fig. 3.1-3).
2. When treating CMP backflow sludge and the original CMP wastewater with PAC, different PAC dosages and different backflow sludge volumes yielded a variety of outcomes of the turbidity reducing efficiency. The turbidity reducing efficiency has a mainly direct proportion to the increase of the PAC dosage (Fig. 3.1-4).

3. Comparing the PAC dosages used between dealing with CMP wastewater with and without backflow, a 4.5 NTU was read when using a 40 mg/L as Al₂O₃ dosage of PAC without CMP sludge backflow. When a 26 mg/L as Al₂O₃ PAC dosage was used with 5 ml of backflow sludge, a 4.9 NTU was read. And when a 27 mg/L as Al₂O₃ PAC dosage was added with 8 ml backflow sludge, the turbidity could be reduced to a value of 2.4 NTU. The data was shown in Fig. 3.1-5 and Fig. 3.1-6.

3.2 Experiment on treating CMP + BG wastewater

Comparing the particle size distribution figure of CMP wastewater (Fig. 3.2-1), BG wastewater (Fig. 3.2-2) and CMP + BG wastewater (Fig. 3.2-3), the gathering situation of particle size distribution of CMP wastewater and BG wastewater broke after mixing these two kinds of wastewater. Larger diameter particles were formed, which proved that mixing these two kinds of wastewater destroyed the original stability.

3.2.1 Data analysis

1. 0.05%–1% sludge backflow volume was mixed with CMP + BG wastewater. The particle size distribution curve moved towards a larger diameter when the rate of backflow sludge is 0.6%. However, when the sludge was added to more than 1%, the distribution curve doesn’t move towards the larger diameter. (Fig. 3.2-4, Fig. 3.2-5, Fig. 3.2-6, Fig. 3.2-7)
2. When FSC-888 dosage was reduced to 450PPM /400PPM/350PPM respectively, and various volumes of sludge were added, the turbidity of the upper layer liquid after treatment could be improved with a backflow rate of 0.2%-0.4% (Fig. 3.2-8).

4. Conclusions

The first experimental data are shown in Fig. 3.1-5 and Fig. 3.1-6, with the results as follows:

<table>
<thead>
<tr>
<th>BACKFLOW VOLUME (ML)</th>
<th>PAC DOSAGES USED (MG/L AS AL₂O₃)</th>
<th>NTU</th>
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<tbody>
<tr>
<td>0 (without backflow)</td>
<td>40</td>
<td>4.5</td>
</tr>
<tr>
<td>5</td>
<td>26</td>
<td>4.9</td>
</tr>
<tr>
<td>8</td>
<td>27</td>
<td>2.4</td>
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</table>

The second experimental data are shown in Fig. 3.2-8, with the results as follows:

<table>
<thead>
<tr>
<th>BACKFLOW RATE (without backflow)</th>
<th>FSC-888 DOSAGE USED (PPM)</th>
<th>NTU</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>450</td>
<td>19.0</td>
</tr>
<tr>
<td>0.1%</td>
<td>450</td>
<td>18.0</td>
</tr>
<tr>
<td>0.2%</td>
<td>450</td>
<td>2.0</td>
</tr>
<tr>
<td>0.4%</td>
<td>350</td>
<td>6.0</td>
</tr>
<tr>
<td>0.4%</td>
<td>450</td>
<td>3.0</td>
</tr>
<tr>
<td>0.6%</td>
<td>450</td>
<td>5.0</td>
</tr>
</tbody>
</table>

The CMP and BG wastewater of this experiment were sampled from semi-conductor manufacturing factories of the Hsinchu Science Park. Both have high concentrations of suspended solids, which makes it difficult for sedimentation. The differences between CMP wastewater and BG wastewater are the size distribution of the suspended solids (Fig. 3.2-1, Fig. 3.2-2), and the electric charge. The particle size is more focused in the research.

With the improvement of manufacturing, the chemicals applied in the CMP process are
varied. This leads to the replacement of the polishing liquid ingredient, thus making CMP wastewater treatment a difficult task.

Future work could investigate using both PAC and FSC-888 to find out the best proportion of use under different conditions through experimentation to achieve better treatment efficiency.

Acknowledgements

Thank Ting-Yu Tsai and Shan-Hsiu Wei for helping data collecting.
References


Analysis of CMP waste water: pH, NTU, and particle size distribution

Experiment without CMP sludge backflow

Examine the best experimental pH condition, the dosage of PAC, and turbidity

Experiment with CMP sludge backflow

Examine the best experimental pH condition, the dosage of PAC, turbidity, sludge backflow rate, and sludge staying duration

Analysis of CMP waste water after treating: pH, NTU, particle size distribution

Fig. 2.1-1 Experiment procedure of treating CMP wastewater
Analysis of CMP + BG waste water: pH, NTU, and particle size distribution

Experiment without CMP + BG sludge backflow

Examining the best experimental pH condition, the dosage of FSC-888, and turbidity

Experiment with CMP + BG sludge backflow

Examining the best experimental pH condition, the dosage of FSC-888, turbidity, sludge backflow rate, and sludge staying duration

Analysis of CMP + BG waste water after treating: pH, NTU, particle size distribution

Fig. 2.2-1 Experiment procedure of treating CMP + BG wastewater
Fig. 3.1-1 NTU – PAC dosage CMP waste water treated with PAC of different dosages
Fig. 3.1-2 pH – PAC dosage
Fig. 3.1-3 NTU – pH Treat CMP waste water with PAC in variable pH condition yields different NTU values.
Fig. 3.1-4 NTU – PAC dosage Treat CMP backflow sludge accompanies original CMP waste water with PAC.
Fig. 3.1-5 NTU – CMP sludge backflow volume. Compare the PAC dosages used between dealing with CMP waste water with various backflow.
Fig. 3.1-6 NTU - PAC dosage

Compare the PAC dosages used between dealing with CMP waste water without backflow and with backflow.
Fig. 3.2-1 Particle size distribution by volume of CMP waste water

Fig. 3.2-2 Particle size distribution by volume of BG waste water
Fig. 3.2-3 Particle size distribution by volume of CMP + BG waste water

Fig. 3.2-4 Particle size distribution by volume with 0.2% sludge backflow
0.6% sludge return size distribution by volume

Fig. 3.2-5 Particle size distribution by volume with 0.6% sludge backflow

0.8% sludge return size distribution by volume

Fig. 3.2-6 Particle size distribution by volume with 0.8% sludge backflow
Fig. 3.2-7 Particle size distribution by volume with 1% sludge backflow

Fig. 3.2-8 NTU – Sludge backflow rate, when FSC-888 dosages are 450PPM/ 400PPM/ 350PPM respectively
Identification and Source Attribution of the Ambient VOCs in a High-tech Industrial Complex

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Abstract

The subject of this thesis involves analysis of samples taken from Hsinchu Science Park, and several significant factors were focused to discuss the variation tendency of the volatile organic compounds existing in the Hsinchu Science Park environment. Principal Component Analysis (PCA) accompanied with MATLAB software was applied to sort and to analyze the concentration of volatile organic compounds and the sampling sites. In addition, the correlation of contaminants between residential district and the Science Park was taken into consideration. This may well represent the distribution of the volatile organic compounds in this period of time.
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1. Introduction

The main volatile organic compounds in the atmosphere of the Science Park are Acetone, 2-Butanone, IPA and Toluene. The top 10 volatile organic compounds are listed in Table 1-1.

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<tr>
<td>3</td>
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<tr>
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<td>2-Butanone</td>
<td>30.9</td>
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<td>Silane, fluorotrimethyl</td>
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<td>Benzene, 1-ethyl-4-methyl-</td>
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Although the prevention and cure work of factory pollution in the Science Park is above the national standard, a quick index of the air quality in Hsinchu and the Science Park is more persuasive for employees and inhabitants. This experiment is based on the routine examination of Hsinchu Science Park, which contributes to the establishment of the background data aiming at the long-term monitoring of the volatile organic compounds in the atmosphere of the Science Park.
2. Materials and methods

The volatile organic compounds (VOCs) in the environment of the Hsinchu Science Park was measured and analyzed in this experiment. In order to avoid the interference of a considerable quantity of air pollutants emitted from vehicles, the sampling time was set to be in the late evening when there were few cars and motorcycles. The weather and the location of factories were taken into consideration as well for compiling and analyzing the data.

2.1 Target volatile organic compounds (VOCs)

The Target volatile organic compounds in this experiment can be classified into two types, polar compounds and non-polar compounds, according to the polarity. Polar compounds are listed in Table 2-1. Non-polar compounds are listed in Table 2-2.

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<td>Isopropyl Alcohol</td>
</tr>
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</tr>
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<td>2-Butanone</td>
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<td>Butyl acetate</td>
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<td>Freon 114</td>
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<tr>
<td>14</td>
<td>Methyl chloride (chloromethane)</td>
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<tr>
<td>15</td>
<td>Vinyl chloride (chloroethene)</td>
</tr>
<tr>
<td>16</td>
<td>Methyl bromide (bromomethane)</td>
</tr>
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<td>Ethyl chloride (chloroethane)</td>
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<td>18</td>
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<td>Chloroform (trichloromethane)</td>
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<td>m/p-Xylene</td>
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</tr>
<tr>
<td>47</td>
<td>o-Dichlorobenzene</td>
</tr>
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</table>
2.2 Sampling method

The purpose of this subject is focused on the distribution of volatile organic compounds (VOCs), which are emitted from the Science Park factories, in the Science Park and neighbor residential area. Therefore, in terms of sampling tactic, avoiding the influence of interference from traffic air pollutants is the main concern. The major source of volatile organic compounds (VOCs) in the Hsinchu Science Park is from factories and vehicles. Since the emission from vehicles was not the point in the survey, sampling sites were selected from places with lower traffic interference and sampling time was at 10 pm. This can factually express the distribution of the volatile organic compounds emitted from factories according to the measuring result data.

2.3 Sampling site

This research is aimed at volatile organic compounds (VOCs), and sampling sites were located in 34 spots set before as regular examination. There are five sites out of the Science Park and located in residential area.

The sampling sites are shown on the modified map (Fig. 2-1)
2.4 Principal component analysis

2.4.1 Objectives of principal component analysis

- To discover or to reduce the dimensionality of the data set.
- To identify new meaningful underlying variables.

It is a method of identifying patterns in data, and expressing the data in a way as to highlight their similarities and differences. Since patterns in data can be difficult to find in data of high dimension, where the luxury of graphical representation is not available, PCA is a powerful tool for analyzing data.

Another main advantage of PCA is that once patterns were found in the data, the data can be compressed, i.e. by reducing the number of dimensions, without much loss of information. This technique was applied in this research.

2.4.2 Mathematical background of principal component analysis

Eigen analysis is the mathematical technique used in PCA; eigenvalues and eigenvectors are solved from a square symmetric matrix with sums of squares and cross products. The eigenvector associated with the largest eigen-value has the same direction as the first principal component. The eigenvector associated with the second largest eigen-value determines the direction of the second principal component. The sum of the eigenvalues equals the trace of the square matrix and the maximum number of eigenvectors equals the number of rows (or columns) of this matrix.
Steps

-Step 1: To formulate the results in a matrix-A
-Step 2: Calculate the mean and standard deviation
-Step 3: Compute the correlation coefficient matrix of A
-Step 4: Calculate the eigenvectors and eigen-values of the correlation coefficient matrix

Since the covariance matrix is square, eigenvectors and eigen-values can be calculated for this matrix. And thus provides significant useful information about the data.
-Step 5: Calculate the principal components

3. Results and discussion

3.1 VOCs result data

The result data of the volatile organic compounds (VOCs) examination are shown in Table 3-1 to Table 3-5.

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Unit: ppbv
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Unit: ppbv
### Table 3-4. Volatile organic compounds (VOCs) in Phase-1 Area (Area D)

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Unit: ppbv

### Table 3-5. Volatile organic compounds (VOCs) in Residential Area (Area E)

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Unit: ppbv
3.2 Significant emission distribution

Four significant emission, acetone, 2-butanone, IPA and toluene data acquired above were illustrated (Fig. 3-1). The first figure reveals that acetone apparently concentrates on two main areas which are Area C and Area D (Phase-1 Area). The second figure shows the distribution of 2-butanone that a major concentration of 2-butanone is in the Area D (Phase-1 Area) and another is on the edge between Area A (Phase-3 Area) and residential area. The distribution of IPA is illustrated as the third figure, focuses in Area C and Area D (Phase-1 Area), revealing a similar distribution as that of acetone. Toluene distribution is drawn in the forth figure, it shows three main parts with high concentration of toluene, which are at the border between Area C (Phase-1 Area) and Area B (Phase-2 Area), and in Area D (Phase-1 Area). These four figures present a centralization of significant emission, which gathers primarily in Area C and Area D (Phase-1 Area) and the ambient edge. This state indicates a tendency of higher concentration of significant emission in the earliest developed area, Phase-1 Area, in the science park. Phase-1 Area lacks regulation on dealing with pollutants since the early time and thus emits more VOCs to the air, while the later developed areas have a better control on the releasing of volatile organic compounds.
Fig. 3-1 Significant Emission Distribution

Acetone

2-Butanone
3.3 Factor weighting distribution

The result figure from the MATLAB software reveals the relationship among the volatile organic compounds from the whole Science Part area (Fig. 3-2). Ketones, chlorides and phenyl group aggregate separately and form into clusters. The other phenyl group compounds on this figure congregate with methyl chlorides. This indicates that polar compounds tend toward the positive directive of the y-axis and non-polar compounds aggregate around 0 of the y-axis. Polar volatile organic compounds are the main emission of photoelectric industry and semiconductor industry companies, while non-polar volatile organic compounds chiefly come from vehicles.

3.4 Principal components weighting distribution

The results of the Principal Components Weighting Distribution calculated from MATLAB were illustrated in the distribution figure (Fig. 3-3). According to the Factor Weighting Distribution figure, the sampling site points in the Principal Components Weighting Distribution figure can be analyzed to be that those site points which have the tendency to be situated at the negative side of the y-axis have more quantity of polar volatile organic compounds contained. Meanwhile, points located in the positive side of y-axis and near 0 are mainly sites with more non-polar volatile organic compounds which come from vehicles passing by.
3.5 Inferences

The Phase-3 Area (Area A) contains mostly photoelectric industry and semiconductor industry companies, which emit mostly the same volatile organic compounds to the air, therefore, the results of sampling sites in the Area A all fall on the fourth quadrant in the figure of principal components weighting distribution.

The Phase-2 Area (Area B) is mainly composed of semiconductor industry companies which produce chiefly the same volatile organic compounds as Area A. Six sampling sites drop on the fourth quadrant as the sites of Area A do. However, B5, B6 and B9 exceptionally fall on the first, second and third quadrants respectively. This appearance could be reasonably explained due to the location of Area B. In terms of the location of Area B, it has a long border with Area C and downtown Hsinchu, so the atmosphere may comprise air from Area C and from Hainchu downtown, and the samples were thus mixed with air from these two areas. This leads to the result of the exceptional B5, B6 and B9 dropping out of the fourth quadrant in the figure of principal components weighting distribution.

The Phase-1 Area (Area C and Area D) is the first development of the Science Park, companies in this area include not only photoelectric industry and semiconductor industry, but also mechanical industry and other traditional industries. Various types of products are manufactured in this area, and the processes of those products bring forth a great diversity of volatile organic compounds. This results in the distribution of the sampling sites of Area C and Area D in the first, second and forth quadrants in the principal components weighting distribution figure.

Area E is a residential district adjacent to the Science Park, and a feature could be found in the principal components weighting distribution figure, that all sampling sites of Area E fall
in the forth quadrant.

4. Conclusions

The concentration of non-polar compounds apparently to be lower in the Science Park, and non-polar compounds come from vehicles, therefore, it can be reasoned that these non-polar compounds were contributed by cars and motorcycles, and more vehicles appear outside the Science Park than inside during nighttime.

Polar compounds are produced from the factories in the Science Park, however, these substances were found outside the Science Park, this could be caused by the speed and direction of wind. Phase-3 Area (Area A) has a superiority of fluent air circulating, this prevents pollutants from accumulating.

In terms of the areas, Phase-1 Area (Area C and D) is the most contaminated area, and Phase-2 Area (Area B) is the second one.

To achieve a prompt and proper environment monitoring, the Principal Component Analysis (PCA) can be constructive accompanied with effective software. This technique could be gradually corrected to achieve a higher accuracy as an index.

Acknowledgements

Thank Bei-Ren Wu, Jung-Pin Yu and Jue-Chi Chang for helping data collecting.
References


Appendix

MATLAB data