



The cold air machine

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Abstract

This study focuses on the human behaviour in regards of air-conditioning usage in indoor environment. A mid-sized, carpet floored office (600 sqm) with 120 employees in Hong Kong was chosen as the experiment field due to two reasons. The first reason is that the office buildings in Hong Kong are the coldest office buildings worldwide. And the building where the office is located doesn't provide a central air-conditioning system, which means that the human behaviour is very crucial to save energy in such offices. The second reason is that the largest portion of electricity consumption in Hong Kong belongs to the air-conditioning systems in buildings (25% of total electricity consumption in Hong Kong). Development and usage of energy efficient technologies are no doubt very crucial in emission reduction and environmental protection. But, the best energy efficient equipment is not much worth and waste of money if the behaviour of the persons using that equipment does not change. In this study we searched for the reasons behind the persistent behaviour of wrongly using the air conditioning systems and making Hong Kong probably the city with the largest energy consumption for cooling per square meter.

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Keywords: Air-conditioning, Human behaviour, Indoor air quality, Office building, Overcooling.

1. Introduction

What is the reason of overcooling the buildings (offices, cinemas, shopping malls etc.) and even mass transport vehicles (buses, minibuses and trains) in Hong Kong? Is it maybe a mistranslation of the word "air-conditioner" into Cantonese as mentioned by some experts from the Hong Kong Polytechnic University? In 1950s, "air-conditioner" was translated into Cantonese as "cold air machine". As a result, people expect it to produce a cold environment rather than what the scientists describe as proper thermal comfort - a temperature which allows you to work without feeling uncomfortable [1].

According to the Environmental Protection Department of Hong Kong, buildings account for some 89% of the electricity consumed in Hong Kong [2]. Up to 28% of this electricity is consumed for space conditioning [3]. At the end one can say that 25% ($0.89 * 0.28 = 0.25$) of the electricity in Hong Kong is consumed for air-conditioning the buildings. Hence the reduction of amount of electricity consumed for air-conditioning is crucial in reduction of the greenhouse gas emissions. There are several developments and applications to achieve reductions of up to 48% of air-conditioning energy on the technical side, as also shown in a case study in Hong Kong [4]. But, the human behaviour is not less important as it will be further elaborated in this study.

2. Air-conditioning system in the office

The office is cooled by air-cooled chiller units, which are located outside of the windows as shown in Figure 1. There is no fresh air supply through the ducts. The only fresh air supply is through some openings above the windows, as shown on Figure 2. The indoor units are shown in Figure 3 and are individually controlled.

On technical side, the air-conditioning system of this office is very simple and there is no question that there are much better designs available on the market. But this office represents many of its kind in Hong Kong and regardless of the technical equipments and design; we focus more on the human behaviour in this study and show the energy saving potential by just changing the behaviour of the office workers. At the end, a proper behaviour is applicable for all kind of buildings regardless their technical facilities.



Figure 1. Outdoor unit



Figure 2. Window openings

3. Behaviour of office workers

The indoor temperature was measured throughout the year and the 120 people working in the office were observed and questioned regarding their behaviour. The results can be summarized as follows:

- The average indoor temperature was found as 20.5°C, which is 5°C lower than 25.5°C, which is suggested by the Hong Kong government since the 1970s.
- The average indoor CO₂ concentration was measured as 1200ppm.
- 104 out of 120 people have an additional clothing (jackets, shawls etc.) just to keep them warm inside the office.
- 16 people think that the indoor temperature is just right for their comfort to work without a jacket.
- 65 people think that it is normal to sit with jacket in the office and they feel comfortable working with jacket by turning down the temperature setting.
- 33 people feel that the office is actually too cold but they also think that this is normal and everywhere is similar in Hong Kong.
- 12 people are not happy with the cold indoor air and feel uncomfortable.



Figure 3. Indoor unit

4. Two experiments

One of the energy saving measures in Hong Kong is to turn off the air-conditioners in winter, during the four cooler months from November to February. This was done for 1 day as an experiment to see whether the office workers felt comfortable with this and also another experiment was carried out to understand the wasteful behaviour of office workers.

4.1 First experiment

The first experiment carried out was turning off all air-conditioners for 1 whole day in November and opening the windows. The outdoor temperature was 24°C on that day.

The measured CO₂ concentration, daytime air temperature and relative humidity inside the office were as follows:

- The day before the experiment: 1220ppm, 19.5°C, 53%
- On experiment day: 780ppm, 25.5°C, 60%
- The day after the experiment: 1150ppm, 20°C, 54%

After the experiment, the office workers were asked about their opinion, whether they prefer to work in an office cooled by air-conditioners or just by natural ventilation. 69% prefer the air-conditioning, 19% feel comfortable with both and only 12% preferred the natural ventilated office. Those, who voted for the air-conditioning, gave the following reasons:

- They breath better when the air-conditioner is running
- They sweat when the air-conditioner is off
- The office smells bad when air-conditioner is off
- Outside noise from open windows

We don't consider the noise as a big problem because the running air-conditioners have already a background noise, which the people got used to. By opening the windows and because of the lacking background noise of the air-conditioners, the noise from the light traffic on a non-busy street (10 floors lower than the office) was the reason why some people got disturbed from it.

We also don't consider the higher temperature as a real problem since it is exactly inline with the recommended temperature of 25.5°C and there are several campaigns such as Cool Biz in Japan, to encourage office workers to wear more casual clothing in the office. But the complaint regarding the bad smell was quite interesting and worth to further investigate. Most of the people stated that the office smells bad and they can't breathe well when the air-conditioner is turned off. But, on this day the measured CO₂ concentration was around 400ppm lower than usual (because of the permanent ventilation) and there was no special smell coming from outside.

These results can be explained by two means. Firstly, it has become a habit in Hong Kong to run the air-conditioners at high power. The cooler the shopping mall, the better. This is also valid for all kind of other buildings. In some cinemas, it is even possible to borrow shawls from the cinema staff when sitting for several hours in a room, which is 18°C only.

Dr. Daniel Chan Wai-tin, Associate Professor at the Department of Building Services Engineering of the Hong Kong Polytechnic University, conducted a research on thermal comfort in office premises and found the indoor temperature of most of the offices is around 21°C to 22°C with the coldest at 17.6°C, far below the sensible range at around 25°C.

"Hong Kong has the coldest air-conditioned environment in the world. Hong Kong people call the air-conditioner as 'cold air machine' and expect cold air to come out from it. The naming has resulted the overcooling of the indoor environment since the engineers tend to set the thermostat at a lower temperature to avoid complaints from the people about not making the air-conditioner cold enough. The air-conditioning is thus set to cool the clothing." Chan points out, "If you unbutton your collar, or roll up your shirtsleeves, you could feel at least up to one Celsius degree cooler. No need to turn down the air-conditioner."

The second explanation might be that the smelling sensitivity reduces at low temperatures. So, even the CO₂ concentration is high, people may still sense the indoor air as fresh if it is cold enough. There are several studies showing this relationship between smell sensitivity and low temperature.

One of the studies was carried out in Malaysia, which has a tropical climate and usually air-conditioned indoor environment.

This cross-sectional study involved 50 subjects without nasal obstruction. All these subjects were given a questionnaire to determine nasal obstruction subjectively on a visual analogue scale. The study was conducted in two separate rooms in the departmental laboratory where the temperatures were maintained at 30-33 degrees Celsius and an air-conditioned room at 18-22 degrees Celsius, respectively.

The study revealed that subjective nasal patency is reduced and increased in nasal resistance in air-conditioned environment compared to room temperature [5]. Furthermore, there are several studies showing that a decreased relative humidity at room temperature is also increasing the nasal resistance. An increased nasal resistance, together with decreased odour concentration (due to the low temperatures and relative humidity) may have the result that people feel the colder and dryer air-conditioned air more fresh than the air at room temperature. The following experiment was carried out in a meeting room to further study this case.

4.2 Second experiment

This experiment was carried out in a meeting room of size 20 sqm with individually controlled air handling unit including two air outlets (Figure 4). 10 people were asked to stay in the room for 5 minutes and give their opinion afterwards. They were asked to choose between condition A or B.

Condition A: The room was well ventilated before the experiment. Air-conditioner was on. The indoor temperature and relative humidity were kept at 19.5°C and 50% respectively. The CO₂ concentration was 1200ppm.

Condition B: The room was well ventilated before the experiment. Air-conditioner was off. The indoor temperature and relative humidity were kept at 25.5°C and 50% respectively. The CO₂ concentration was 1200ppm.

So, the only difference between the two conditions were the temperature and the on / off state of the air-conditioner.

The result was that 8 of 10 subjects preferred Condition A. 1 subject preferred Condition B. 1 subject felt comfortable in both conditions. The comments were similar to those from the first experiment. Those, who preferred Condition A, gave the following reasons:

- fresh air
- better smell
- easier breathing

Obviously, a colder air was felt by the subjects as more fresh. Not last, this is also related to the increased nasal resistance and the decreased nasal patency, which reduces the smell sensitivity. Also the items in the room, especially the carpet evaporates unpleasant odour, which is increased at higher temperatures. All together, plus being used to cold indoor environment, made the subjects feel better in an air-conditioned room.

Covering the floor by tiles instead of a carpet would definitely decrease the bad odours inside the office and would make it easier for the office workers to turn up the air-conditioners.



Figure 4. Air-conditioner unit in the meeting room

5. Conclusion

The findings from the performed experiments show clearly that the comfort of an overcooled office is mostly subjective. Even in some cases the CO₂ concentration is higher, people still prefer a colder office rather than a reasonable working environment at 25.5°C. Even many people feel actually cold, but they still prefer to use jackets in an overcooled room rather than turning up the air-conditioner and adjusting their clothing. It is a tremendous amount of energy and money, which is continuously wasted to keep Hong Kong indoors overcooled. At the end, it is the environment, which suffers from this unreasonable behaviour. We believe that only with education and arising public awareness, the wrong behaviour of the air-conditioner users can be changed. Is it the habit of wrong usage of the air-conditioners; or, is it really because of the mistranslation made 50 years ago?

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