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Indoor–outdoor relationships of particulate matter and nitrogen oxides under different outdoor meteorological conditions

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Abstract

Respirable suspended particulate matter and nitrogen oxides concentrations were measured inside and outside a student office in an urban location during a 9-month period. Direct reading tapered-element oscillating microbalance (TEOM) instruments and passive sampling techniques were used to provide indoor and outdoor hourly averages of the two pollutants during the sampling period. The variations and correlations of the pollutant concentrations and the indoor–outdoor (IO) ratio against various outdoor meteorological factors, namely temperature, humidity, pressure, wind speed and solar irradiation were studied. Using a data-mining procedure, suitable sets of data were amassed and grouped together to study the effect of these individual weather parameters on the IO ratio. It is found through statistical regression techniques that temperature, humidity and solar irradiation play a vital role in the variation of the IO ratio. In fact, the IO ratio shows convincing tendency of increase with increase of these three weather parameters. On the other hand, both pressure and wind speed seems to have relatively little effect on the IO ratio.

Keywords: Indoor air; Indoor/outdoor relationship; Regression models; Meteorological conditions; Respirable suspended particulate; Nitrogen oxides

1. Introduction

Indoor air quality (IAQ) has gained great attention in recent years, chiefly due to the large amount of time we spend indoors in modern times. Jenkins et al. (1992) showed that urban people spend on average 87% indoors and only a mere 6% outdoors. We also tend to believe that the indoor environment is better and more livable than the outdoor environment, being cleaner, more comfortable and healthier on the obvious ground that the building will shelter us from harmful substances in the ambient environment. For this reason a number of air quality indication systems in the world, which are designed for outdoor use also, gives warnings or advice during episodes of poor air quality, to stay indoors (Chan and Wong, 2001). However, the fundamental question is: Is indoor air really cleaner? Is it cleared of outdoor pollutants?

Firstly, it must be recognized that indoor air is simply an extension of the ambient air. Air penetrates indoors through doors, windows, air conditioners and so on. Assuming there is no indoor source of pollutant, the entering air would be filtrated by whatever it passes through. However, whether this process effectively removes any pollutant is doubtful, not to mention the fact that it could actually add other pollutants into the air stream. Secondly, due to the substantial difference in climatic environment between indoors and outdoors, this could bring vastly different pollution environment and dispersion characteristics in the two settings. For example in a humid or rainy day, outdoor pollutants

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tend to be washed out while, due to the relative constant humidity indoor, indoor air quality could be much worse, without even looking at any indoor activity. Thirdly, as Yocom (1982) pointed out, indoor–outdoor relationships are a complex interactions of various factors like meteorological factors, indoor sources and sinks, pollutant depletions, filtrations and ventilations, etc. Moreover, the air pollutants indoors and outdoors differ in types, characteristics, concentrations and sources. For example, smoking and cooking have been identified as major sources of indoor pollutants which are insignificant outdoors (Repace and Lowrey, 1980; Allen and Miguel, 1995; Jones et al., 2000). Hence, blindly assuming that indoor air is cleaner due to its apparent shielding from outdoors is both unreasonable and unwise. It is, therefore, also important to determine how outdoor air quality can affect indoor air quality according to Yocom's (1982) suggested factors.

With this objective in mind, a number of studies have been devoted to characterize the relationship between indoor and outdoor air quality (Anderson, 1972; Dockery et al., 1981). Dockery and Spengler (1981) studied the indoor/outdoor relationships (IO) of sulphates and particles. They found that the mean infiltration rate of outdoor fine particulates was approximately 70%, and that full air conditioning can reduce this rate by about half. However, the negative note about air conditioning is that it also prevents indoor pollutants dilution and diffusion to outdoors. Molhave et al. (2000) analysed the house dust collected in seven Danish offices and partially confirmed such an assertion. Quackenboss (1989) studied the IO relationship of particulate matter and its related health effects. Kamens et al. (1991) studied the indoor pollutant characteristics for three non-smoking homes and associated the aerosol size to the various human activities. Clayton et al. (1993) sampled the aerosol distribution and concentrations in indoor and outdoor environments. Lee et al. (1997) studied the air quality during the summer seasons in Korea. Their field measurements showed that outdoor air contributed 50–100% of indoor pollution environment in their situation. Monn et al. (1997) and Jones et al. (2000) measured the IO relationships of particulate matters in roadside, urban and rural locations. Kingham et al. (2000) studied the spatial variation of traffic-related pollutants concentration in the IO context in Huddersfield and their measurement data suggested that strong correlation existed between indoor and outdoor air pollution levels. Besides experimental or field measurements, modelling studies have been performed by Shair and Heitner (1974) and Freijer and Bloemen (2000). In particular, the model by Freijer and Bloemen (2000) evaluated the transient IO ratio and is applicable to different ventilation scenarios, pollution sources and sinks. More recently, Koponen et al. (2001) studied the effect of outdoor air pollution on indoor air with emphasis on the ventilation system. They found that, at least in their scenario, indoor particles were mainly of outdoor origin and that the ventilation had a strong influence on indoor particle characteristics and concentrations. In summary, despite the huge variety of these studies in terms of conditions and results, most of them are able to demonstrate a certain degree of correlation between indoor and outdoor air, with such relation depending obviously on a large number of factors like ventilation system, indoor/outdoor activities, geographical settings, weather conditions, etc.

Looking at previous literatures, in spite of the observed correlations, it is not difficult to see that the IO relationship can vary quite largely (from 0.1 to as high as 20). It is, therefore, quite difficult to give a fair and assertive judgment as to whether indoor air is better than outdoor air or vice versa. Obviously, a large number of factors might have been involved, but it is not unreasonable to believe at least one of the reasons behind this large variety of results is the varying weather conditions. Differences in temperature, humidity, pressure, atmospheric stability, solar irradiation, wind condition, etc. between the ever-changing outdoor and controlled indoor environment can all alter the penetration rate of outdoor air into built environment, no matter what airflow systems we are referring to. As far as general air quality and weather are concerned, Chan et al. (2001) and García-Talavera et al. (2001) have studied the meteorological effects of pollutant dispersion and aerosol radioactivity, respectively. Other literatures (Lee et al., 1997; Koponen et al., 2001) have also taken qualitative account of meteorological variations in the analysis of IO relationships. As far as we are concerned, most of the studies focussed on either the spatial variations or activity effects on the IO relationship, whereas there are very few literatures devoted specifically to meteorological variations, with knowledge that it can affect appreciably measurement results. It is felt that the problem of indoor air quality with respect to weather is an area which is not properly addressed and where we would like to insert an effort into.

In this work, we would like to investigate the IO relationship of respirable suspended particulate (RSP) and nitrogen oxides (NO_x) under different meteorological conditions. The following meteorological parameters were monitored in an attempt to study their effects on the IO relationship of air pollutants: temperature, pressure, humidity, wind speed and solar irradiation. The pollutants RSP and NO_x are chosen for the reason that they are common in both indoor and outdoor environments and that one is gaseous and the other is particulate, which represent the two major types of airborne pollutants. More importantly they are predominantly outdoor generated (Yocom, 1982) and so they could give some indication on how weather conditions affect the penetration of pollutants and how well the built environment shelters us from outdoor pollutants. These also represent traffic-related pollutant which is the main problem in the urban areas of Hong Kong.

2. Methodology

Measurements were made constantly for 9 months (from March to December) at the Yam Pak Building of The University of Hong Kong. The area to be studied is the Yam Pak Building and the nearby Pokfulam Road area. The road in consideration is the main road that links the western and southern parts of Hong Kong Island. About 1800–2500 vehicles use the Pokfulam Road during daytime. The vehicles using the road include private cars, buses, mini-buses, trucks and motorcycles.

The mode wind direction during the sampling period was pre-dominantly south and southwest, that is along the road. The wind speed 10 m above the ground level usually fell into the range 0.0–2.5 $m\,s^{-1}$ (except under exceptionally windy days under consideration). The temperature during the diurnal period ranges from 10°C to 35°C and the ambient pressure varies insignificantly between 99.6 and 101.6 kPa. Indoor temperature and humidity were maintained by the air conditioner by its thermostat at 22°C and 60% throughout, respectively, with inevitable minor temporal fluctuations. The air conditioner is switched on at all times and it maintains and controls the overall indoor climate to its specified temperature and humidity well (22 ± 0.5°C and 60 ± 5%). The air conditioner is the only mechanical ventilation system inside the room and has a standard EU7 filter installed. The airflow rate of the air conditioner obviously changes from time to time but fluctuates around 0.075 $m^3\,s^{-1}$. The air exchange rates between the indoor and outdoor environments under normal circumstances were measured using Wallace (1996) blower doors pressurization method and was found to range from 0.50 to 0.80 ach (air change per hour).

Sampling is mainly carried out outside and inside the research students' office located on the first floor of the building. All windows of the office remained closed normally during the entire sampling period, except for the one for use in outdoor sampling, which is left slightly ajar to accommodate the cables and tubings of the instruments. The opening of this window was <1 cm wide and while this is inevitable in our experiment arrangement, the leakage effect is negligible, comparing the air exchange rate with other 'sealed' buildings (Wallace, 1996). Thus, air entry/exit comes mainly from the doorway, this window and the air conditioner, which is set in vent position at all times. The doorway of the office is connected directly to the staircase which leads to the main entrance of the building. Activities inside are mainly normal student office activities and computer work. Throughout the period, students inside the office were asked to keep a record of any anomalous activities inside the office including switching on gas-pipes, burning materials, prolonged entry of visitors, cleaning, etc.

Direct reading Ruprecht and Patashnick 1400a tapered-element oscillating microbalances (TEOM) ambient particle monitors were used to monitor the RSP concentrations inside and outside the building. Both sets of instruments were placed at identical heights above the ground and 5 m away from the air-conditioner vent, one indoors and the other outdoors. Both instruments were housed inside weather and noise proof cabinets to prevent weathering and disturbance to people. The two instrument sets were carefully calibrated and compared before and after the measurements and gave readings to the accuracy of 0.5% of each other. Since we are not interested in identifying individual sources, the data (taken at every hour, daily starting at 9:00 a.m. till 6 : 00 p.m.) were averaged over 1 h to reduce the response time (compared with 10 min by Jones et al. (2000)). A long-average time also eliminates minor fluctuations due to variations of activities as observed in Jones et al. (2000). Sampling of NO_x was carried also on hourly basis at the same time using Ogawa passive sampler through analysis by Shimadzu ion-chromatography (IC) system. Local meteorological conditions (temperature, humidty, wind speed, pressure and solar irradiation) were taken using an AutoMet real-time digital meteorological system located on the roof of the building. All meteorological conditions were also averaged by an hourly basis for comparison purposes.

More than 1200 sets of data were collected during the 9-month period. All data were then meticulously classified according to their meteorological parameters. Since the IO relationship is probably the resultant interactions of all meteorological parameters plus other anthropogenic factors together and we can have no control on the variation of local weather, in order to find the effects of one particular parameter, the following strategy was followed: To consider the effect of say temperature, we have to ensure the other parameters like humidity to be in control mode. While we can do so for artificial effects, we can do nothing to control external weather. We shall thus have to be contented that a variation within ±5% of other weather parameters from the mean of the entire spectrum of variation be regarded as constant (temperature by 1°C, humidity by 2.5%, pressure by 50 Pa, wind speed by 0.1 $m\,s^{-1}$, solar irradiation by 25 $W\,m^{-2}$). Using this criterion, we perform a data-mining procedure through a devised algorithm to extract the useful data for analyses.

3. Results and discussions

The IO ratio, in the simplest arguments, depends ultimately on several parameters: outdoor pollution level C_O, indoor pollutant sources S_{source}, source ventilation rate q_{source}, indoor pollutant sinks S_{sink}, sink ventilation rate q_{sink} as indicated by the equation

$$\frac{C_I}{C_O} = 1 + \frac{1}{C_O}\left(\frac{S_{source}}{q_{source}} - \frac{S_{sink}}{q_{sink}}\right), \quad (1)$$

where C_I is the indoor concentration and the fraction on the left of Eq. (1) is essentially the IO ratio. We shall surround our explanations based on this equation.

3.1. *Daily IO variations*

Fig. 1a and b show a typical daily indoor/outdoor variation of $PM_{2.5}$ and NO_x. In this particular summer day of relatively low sunshine and low humidity, no particular anomalous activity was performed inside the laboratory. In general the NO_x concentrations are lower indoors than outdoors throughout the day, while for RSP it is so only in the morning, during lunch hour and after-work hours. The variations of indoor pollutants are also smaller and more gradual than that outdoors, which is a trend similar to that observed by Koponen et al. (2001). The average IO ratio is 0.7887 for RSP and 0.5623 for NO_x, respectively. The two respective peaks of IO (approximately 11:00 and 16:00) for both pollutants are indicative of the combined effects of increased human activities (increase of S_{source}) and reduced traffic (decrease of C_O) during working hours, while the three minima represent increased traffic and absence of human activities during peak hours and lunch time. Maximum elevations of RSP concentration are also observed in the afternoon, which suggest extra human movements due to increased number of people in the room (Jones et al., 2000), which is an increase of S_{source}. It is also observed during this period that the IO value is higher than 1 for RSP with two probable reasons suggested: extra human movements, reduced traffic loads and higher outdoor temperature causing net inflow of pollutants (negative q_{source}, to be explained later). The comparatively higher IO ratio for RSP over NO_x also indicates that human activities are also a more likely source of particulate matter than NO_x indoors. Correlation between indoor and outdoor pollution levels on this day is acceptable ($R^2 = 0.3663$ and 0.1494) (We shall only call a correlation good/satisfactory when $R^2 > 0.4$), the small value is probably attributed to the high fluctuation of modes of activities during the day.

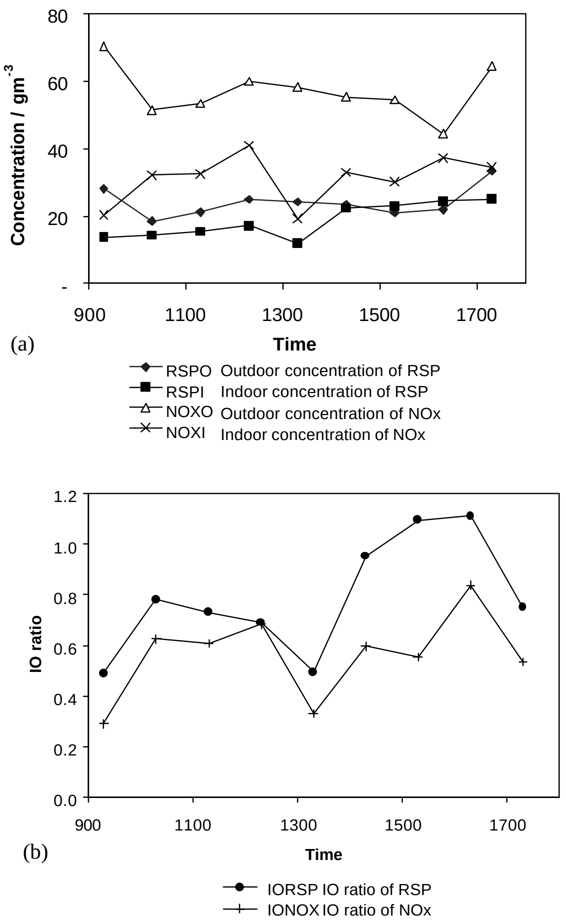

Fig. 1. (a) Daily variation of indoor and outdoor RSP and NO_x concentration (29 August 2000), and (b) Daily variation of IO ratio of RSP and NO_x (29 August 2000).

Fig. 2a and b illustrates the time variation of IO pollutant concentrations on a rainy day. This day is purposefully selected to indicate the effect of rainy days on the IO ratio. In general, outdoor pollution levels for RSP are much lower than that of a normal day while the concentration level remains similar (or only slightly lower) for NO_x. The average IO value is 1.177 for RSP and 0.7507 for NO_x. This shows that high humidity/rainfall can wash out large amounts of outdoor air pollutants (reduced C_O). It can also be asserted that particulate matter are more readily washed out than gaseous pollutants from the exhibition of high IO value. On the other hand, indoor air pollutant concentrations remain slightly higher than other daily data recorded, probably due to the fact that people prefer to stay indoors during rainy days, thus inevitably increasing C_I. A poor correlation between indoor and outdoor air quality was obtained during the day ($R^2 = 0.0156$ and 0.1122 for RSP and NO_x, respectively) due to the large variation of IO and meteorological conditions during the entire day of measurements. In any case, the trend of the daily variation of IO is similar as in the previously shown case with similar peaks at 11:00 and 16:00 observed based on similar explanations. The significance, however, is the extremely high IO ratio (1.500 and

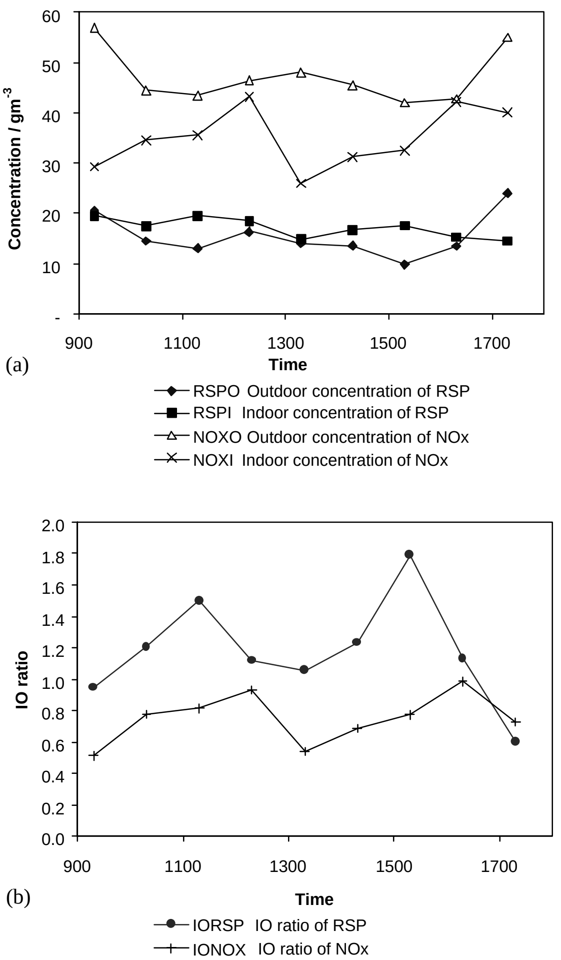

Fig. 2. (a) Daily variation of indoor and outdoor RSP and NO_x concentration (17 October 2000), and (b) Daily variation of IO ratio of RSP and NO_x (17 October 2000).

1.791) due to the comparatively low outdoor pollutant levels. The IO ratios for RSP, as in the previous case, are much higher than NO_x.

Both Figs. 1 and 2 indicate that the IO ratio is at times >1, which seems to suggest the presence of indoor sources. As mentioned already, it is believed that these sources arrive mostly from human activities. This explanation draws from the fact that the IO ratio and the absolute magnitude of the pollutant concentration are both relatively low at hours of low human activities. This is further confirmed by the very small IO ratio at several nighttime calibration measurements when human activities are absolutely absent.

3.2. Effects of temperature

A group of data from the dryer seasons (from September to December) was amassed and assembled to study the effects of outdoor temperature on the IO ratio. The controlling humidity ranges from 58% to 63%, pressure from 100.3 to 100.4 kPa, wind speed from 0.9 to $1.0\,\mathrm{m\,s^{-1}}$, solar irradiation from 460 to $480\,\mathrm{W\,m^{-2}}$. Many of these data were obtained in the afternoon sessions. Fig. 3 shows the variation of IO ratio versus temperature for this set of data. The values of R^2 (0.4049 for RSP and 0.4808 for NO_x) indicate a satisfactory correlation for both pollutants and probably implied that temperature does have a role to play in the IO ratio. Generally it can be seen that the IO ratio increases with increasing temperature, though it has to be admitted that this effect might not be as large as expected (approximately 0.0701 and 0.0755 per °C for RSP and NO_x, respectively, based on regression). It is asserted that such effects is due to the push from thermal diffusion. After all, the natural ventilation rate is a function with the thermal gradient from diffusion arguments. With higher outside temperature, air pollutants are pushed indoors through doorways, window slits, while the vice versa takes place with a lower outdoor temperature. This also explains the small slope of the variation due to the closed windows. On the other hand, it is also noticed that such effect is slightly more prominent for the gaseous pollutant compared with particulate matter. This is attributed to the fact that since the room is relatively well sealed, most of the air comes from the vent of the air conditioner which effectively filters a large part of RSP but probably not NO_x. Mass transport of gaseous pollutants is also obviously easier than particulate matter. Hence in our setting, such penetration mode might favour NO_x than RSP and hence the more prominent the effect for NO_x. Despite this, it can be confidently judged that it is much easier for gaseous pollutants to penetrate indoors than RSP even without the air conditioner. It must also be noticed that in most cases the IO for RSP is slightly

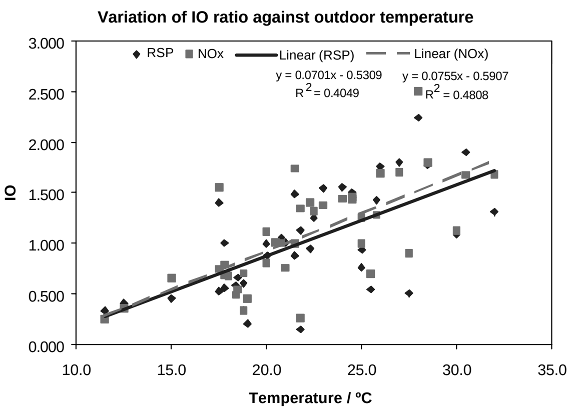

Fig. 3. Variation of IO ratio against outdoor temperature.

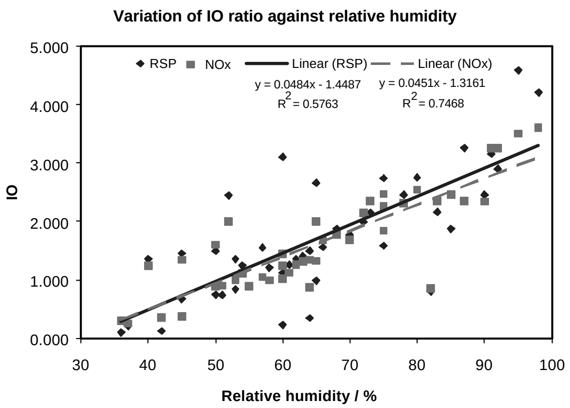

Fig. 4. Variation of IO ratio against relative humidity.

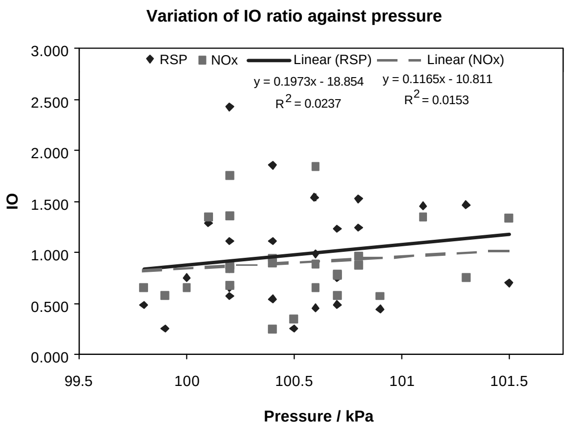

Fig. 5. Variation of IO ratio against pressure.

smaller than that of NO_x, especially for higher temperature (Fig. 4).

3.3. Effects of humidity

Another group of data was similarly assembled to study the effects of outdoor humidity on the IO ratio (Fig. 5). Temperature of this set falls within a narrow range of 18–20°C, with the wind speed 1.5–1.6 m s^{-1}. Pressure remains within the range 99.9–100.0 kPa with solar irradiation 324–356 W m^{-2}. A check with the Hong Kong Observatory records shows that many of these records belong to days with mild drizzles except for the data for low humidity. A strong correlation ($R^2 = 0.5763$ and 0.7468 for RSP and NO_x, respectively) was exhibited, demonstrating that there is actually a close correlation between indoor/outdoor air qualities to outdoor humidity. It can be observed that, in general, the IO ratio increases with increasing outdoor humidity, despite the fact that both indoor and outdoor pollutant concentration levels remained low throughout. This again can be explained by the humidity difference between indoors and outdoors. The indoor environment is a constant humidity chamber where pollutant dispersion is almost in control mode. On the other hand, both RSP and NO_x are readily absorbed or washed out by water vapour in the atmosphere, with probably particulate matter more readily so (thus smaller value of C_O). For obvious reason, the higher the humidity, the more prominent this effect. With less pollutant outdoors and less pollutant entry, indoor pollutant level will be dominated by indoor sources which raises the overall IO level. It can be seen for very humid days, which also corresponds to rainy days, outdoor pollution level is actually very low which in turn makes the IO ratio substantially high. The IO ratios for RSP are also slightly higher than that of NO_x, which could confirm that the effect of washout is more prominent for RSP than NO_x.

3.4. Effects of pressure

A smaller set of data for the variation of IO ratio with respect to pressure is gathered and plotted as in Fig. 5. This set includes pressure varying from 99.8 to 101.5 kPa, respectively. Other controlling meteorological conditions ranges are: temperature 18–20°C, humidity 72–76%, wind speed 1.5–1.6 m s^{-1} and solar irradiation 650–681 W m^{-2}. These data mostly belong to the wetter seasons. A weak correlation ($R^2 = 0.0237$ and 0.0153) is obtained from this set, demonstrating that pressure seems to have very little effect on the IO ratio. There are perhaps at least two reasons attributed to this: Firstly, pressure does not change significantly throughout the period (<2%) and even if it does change it usually causes global pollutant dispersion changes rather than producing effects on pollutant microscopic movements. Secondly, stemming from the first point, pressure gradient between indoors and outdoors is close to zero, thus there is no additional thrust from pressure and any penetration changes are definitely resultant due to other meteorological factors or human activities rather than pressure itself. In fact it is believed that the set of data is more dominated by the condition of high humidity rather than pressure, which gives a fairly high IO ratio throughout.

3.5. Effects of wind speed

A collection of data from many dryer days has been used to show the effects of wind speed on the IO ratio. Fig. 6 shows the variation of the IO ratio with respect to wind speed at a temperature range of 15–17°C, pressure 101.0–101.1 kPa, humidity 55–60% and solar irradiation

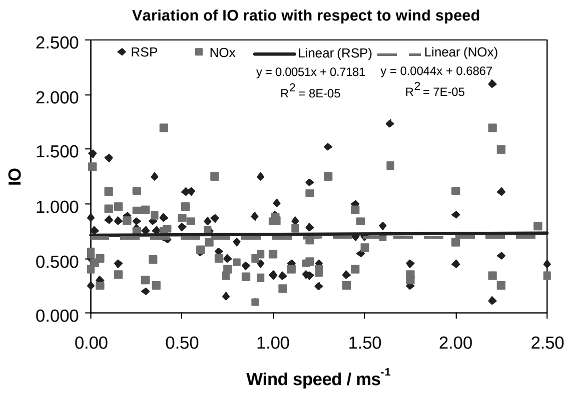

Fig. 6. Variation of IO ratio with respect to wind speed.

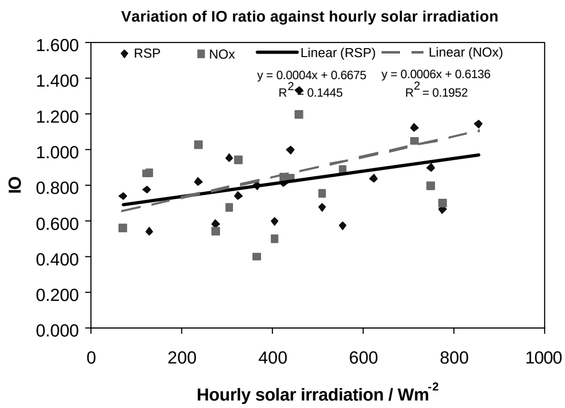

Fig. 7. Variation of IO ratio against hourly solar irradiation.

375–407 W m^{-2}. The IO level for both pollutants fluctuates around the value of 0.75 or slightly lower but with no obvious trend, despite a linear trend line being drawn (In any case the slope of both lines are almost zero.). In fact an extremely low correlation is obtained (R^2 <0.0001 for both pollutants), which suggest that wind speed itself might have little to do with the actual IO ratio. It is expected that the higher wind speed enhances vertical and horizontal dispersions and thus the outdoor air quality will be better from diffusion argument alone (Chan et al., 2001). On the other hand, assuming constant or no peculiar indoor sources, the air will penetrate indoors with low pollutants level (meaning change of IO remains constant) and hence the indoor pollutant level will depend on other factors like the cleanliness of the air conditioner, human activities, etc. rather than the wind speed or dispersion characteristics of outdoor situation.

3.6. Effects of solar irradiation

The effect of solar irradiation is studied since it is connected ultimately with the atmospheric stability which in turn might have significant effect on outdoor pollutant dispersion. Fig. 7 shows the variation of the IO ratio against solar irradiation amongst the chosen data. All of these data arise from summer with temperature ranging from 26°C to 28°C. Humidity falls within a confined range of 70–73%. Pressure changes is minimal amongst the data and ranges from 101.0 to 101.3 kPa while wind speed ranges from 1.0 to 1.1 m s^{-1}. It can be observed that there is a general trend that the IO ratio increases with solar irradiation, despite a weaker correlation than that of temperature variation ($R^2 = 0.1445$ and 0.1952, respectively, for RSP and NO_x). It could be explained that increased solar irradiation generally increases the outdoor temperature which pushes outdoor air indoors through the temperature gradient. Besides, increase of solar irradiation also destabilizes the atmosphere, causing more thorough mixing, dispersion and mobility of pollutants, which also lowers the outdoor air pollutant concentration level, which also tend to increase the IO ratio through increased mobility. This effect is simply a resultant of the decrease of C_O while q and S remain constant. This is more in the case of NO_x as it is a 'lighter' pollutant than RSP and is more prone to dispersion and transport. Stronger solar irradiation also promotes photochemical reactions of NO_x, which subsequently decreases the gaseous pollutant concentration level outdoors but not indoors. This probably explains the higher IO ratio for NO_x than RSP from the graph. The lack of correlation, however, might be due to the fact that solar irradiation also raises the temperature substantially, which causes a lot of data being discarded according to our criteria.

4. Conclusions

Indoor/outdoor ratios for RSP and NO_x are measured in a student office during a 9-month period to study the variation of the IO ratio with respect to different meteorological parameters. It is found that the IO ratio is connected to some meteorological conditions, especially outdoor temperature, humidity and solar irradiation. For example, higher outdoor temperature forces the air indoors through the thermal gradient and thus increases the IO value, whereas high humidity washes out the outdoor pollutant concentration level which also increases the IO ratio. On the other hand, other meteorological parameters like wind speed or pressure seem either to have little effect or that their effects are subdued by the dominant ones.

The incomparable IO ratio for both pollutants also seems to indicate that penetration might not be the only mechanism for pollutants to enter indoors. While it is obvious that NO_x, being gaseous, penetrates indoors easier than RSP, the IO ratio does not generally draw substantial difference with that of RSP. It can only be addressed that indoor sources and sinks for pollutants are equally important in the consideration of the IO values.

Our study is based on the assumption that the IO ratio behaves linearly with these meteorological parameters, presuming there exists any correlation. This assumption is solely based on mathematical simplicity and previous literatures and experience (García-Talavera et al., 2001). It must be honestly admitted that this bears little scientific rigour. The primary objective here is to produce some rules of thumb about the relationships between the IO ratio and weather. Obviously, this assumption is artificial and further work on rigorous modelling of the IO relationship with any parameters must be carried out in future.

It must be emphasized here though, all field data are taken at one particular location with a particular ventilation system with certain modal activities. It needs no emphasis here to say that our results do not represent the general behaviour of the IO relationship. This work simply represents our first step in our attempt to achieve a more profound understanding of indoor air quality and its relationship with outdoor air, in this case, weather conditions in an urban canyon setting is our prime interest. All we can say is that weather conditions have certain relevance in this context and apparently temperature and humidity have a substantial position here. Aside from meteorological variables, there are large number of factors which can play an equally important role in the context, e.g. indoor activities, indoor setting, ventilation system used, roadside condition, geographical location, etc. All these studies will be pursued in the near future.

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