

NO2 DIFFUSION TUBES MEASUREMENT REPORT

CENTRAL AND SHEUNG WAN

Clean Air Network

CAN

健康空氣行動



03 / 2020

Introduction

Central is regarded as the central business district of Hong Kong. However, traffic congestion and lag of greening facilities have contributed to the serious air pollution in Central. According to AADT 2018, the traffic flow in Queen's Road Central, Des Voeux Road Central and Connaught Road Central are much more than that of other streets in Central. Studies have found out that buses and trams are the major source of air pollution, and the air pollution is much more serious on weekdays than weekends. Exposure to nitrogen dioxide (NO_2) is linked with adverse health impacts including aggravation of respiratory diseases and reduction in lung function. Therefore, this project aims to measure the NO_2 concentration in these three crowded streets in Central from Monday to Friday, and compare it with the data provided by the Central Air Monitoring Station, which is a roadside station located in the junction of Chater Road and Des Voeux Road Central.

In addition, due to the Coronavirus disease, most of the office implemented the home office policy from mid-February. The traffic is reduced, and it is predicted that the NO_2 concentration will be reduced. Therefore, we would like to compare the NO_2 concentration with the previous data, to verify that the reduced traffic will reduce the NO_2 concentration in Central.

Besides, recent researches have found out that covered bus terminus are usually with poor air quality because of lack of air filters and poor ventilation. In addition, due to the Coronavirus disease, the bus frequency is reduced. It implies that the passengers are probably spending more time waiting for the bus, and this poses a threat to their health. Therefore, we would like to install 4 NO_2 diffusion tubes (including one field control) in the Exchange Square bus terminus, to compare the NO_2 concentration of covered bus terminus with normal bus stops in Central.

Moreover, a low emission zone has been established since December 2015, and vehicles passing through must meet certain environmental standards. Therefore, in this project, we would like to discuss the effectiveness of low emission zones in reducing air pollutants, and whether the standard should be set stricter. On the other hand, to further reduce the NO_2 concentration in Central, the feasibility of implementing more electric buses routes is discussed.

Methodology

In this project, 10 bus stops and the Air Monitoring Station in Central are selected. These spots are all located in Queen's Road Central, Des Voeux Road Central and Connaught Road Central. Since we would like to measure the NO₂ concentration in working days(from Monday to Friday), the cap of NO₂ diffusion tubes are opened on Mondays and closed on Fridays. To make sure that the sampling time covers the peak traffic hours, we installed the diffusion tubes at 07:30 and removed the tubes at 18:30.

Date of installation	9/3/2020 and 16/3/2020
Date of removal	13/3/2020 and 20/3/2020
Time of installation (on Mondays)	07:30-08:30
Time of removal (on Friday)	18:30-19:30
Venue	11 spots in Central

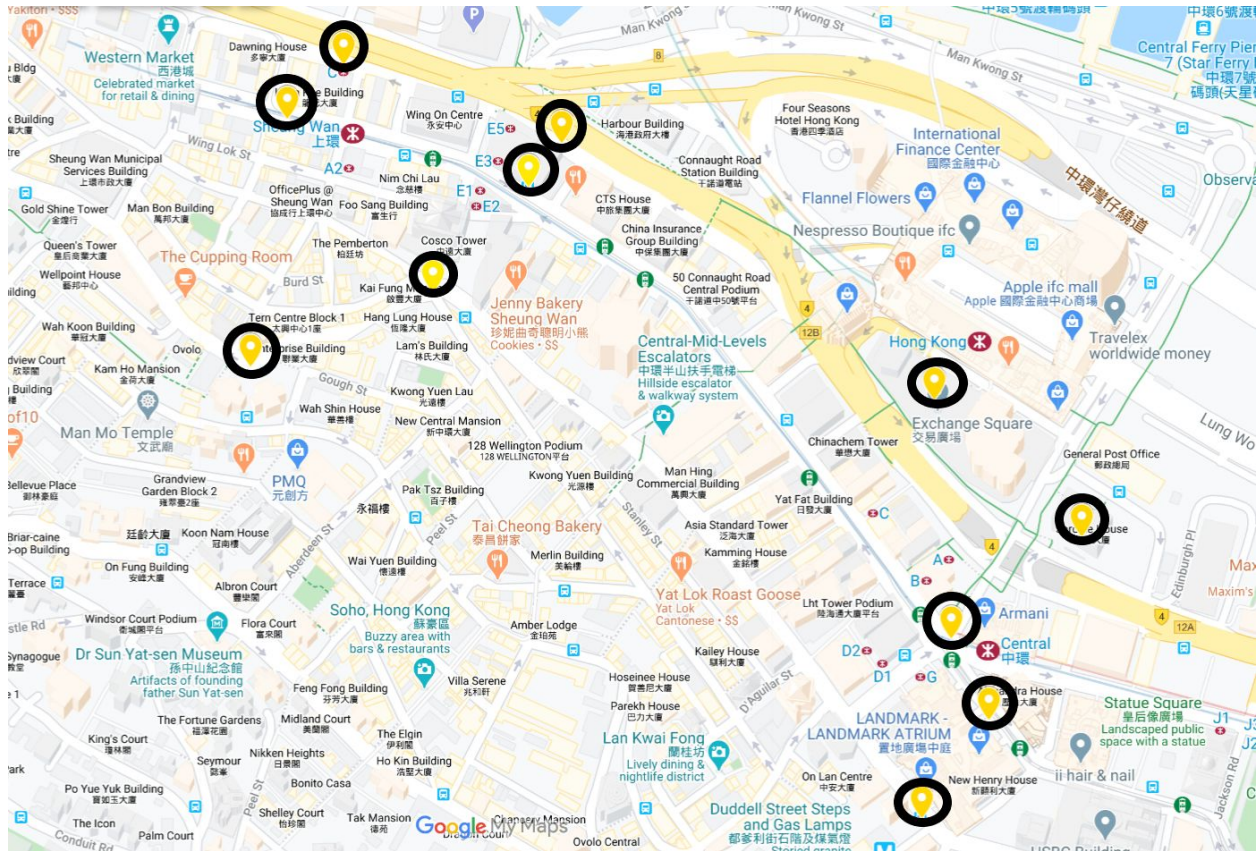


Figure 1: 11 spots of installing NO₂ diffusion tubes in Central

NO₂ diffusion tubes allocation

	Quantity
Installed in different spots (5 of them are field blank)	38
Travel Blank	1
Spare	1
Total	40

Note:

- 1) There are 11 spots in total. Each street will have one field blank.
- 2) For field blank tubes, the cap should not be opened, and measure the background NO₂ concentration on the street.
- 3) For travel blank tube, it will be placed in the refrigerator and measure the two-weeks background concentration.
- 4) If any tube is lost or stolen, the spare tube will replace it.

Results and Discussion

Location	Number of diffusion tubes installed	Number of bus routes	NO ₂ concentration (µg/m ³)
Air Quality Monitoring Station (EPD) Des Voeux Road Central	4 (with one field blank)	/	105.5
Landmark Bus Stop Des Voeux Road Central	3	21	142.9
Cleverly Street, Des Voeux Road Central	3	10	112.3
Rumsey Street, Des Voeux Road Central	4 (with one field blank)	27	134.1
New World Tower (non-franchised) Bus Stop Queen's Road Central	3	2(minibus)	113.4
Wellington Street, Queen's Road Central	3	3	108.7
Hollywood Terrace Queen's Road Central	4 (with one field blank)	11	92.3
Jardine House Bus Stop Connaught Road Central	4 (with one field blank)	47	105.4
Exchange Square Bus Terminal Connaught Road Central (#681)	4 (with one field blank)	30	104.2

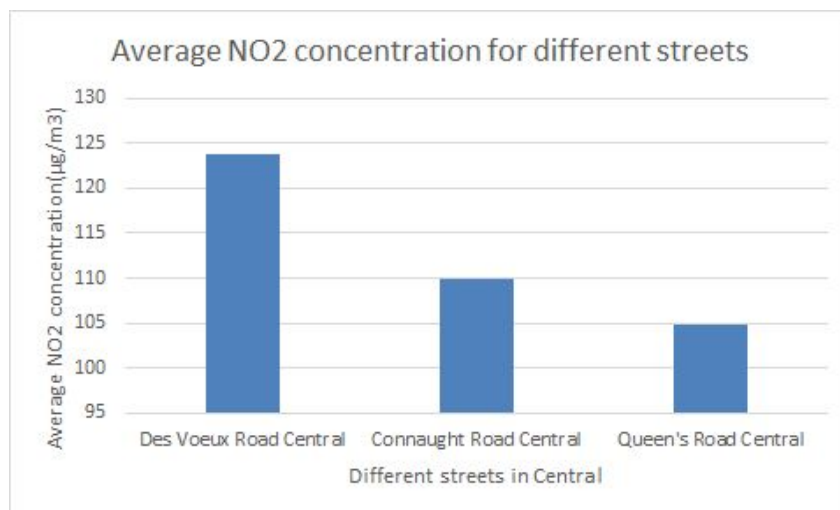
Rumsey Street, Connaught Road Central	3	19	103.8
Hillier Street Connaught Road Central	3	1	126.0

Table 1: NO₂ concentration result in 11 spots of installing NO₂ diffusion tubes in Central

From the table above, although the Landmark is not the location with the largest number of bus routes passing through, it results in the highest NO₂ concentration. On the other hand, the lowest NO₂ concentration is found in Hollywood Terrace, which is the only location with NO₂ concentration lower than 100 µg/m³.

When compared with the results in Sham Shui Po district, we can observe that the air pollution is much more serious in Central and Western districts. The main reason is that there are more special operating routes in Central which operate in peak hours only. Besides, since there are more tall buildings in Central, the street canyon effect traps the air pollutants and hence increases the NO₂ concentration.

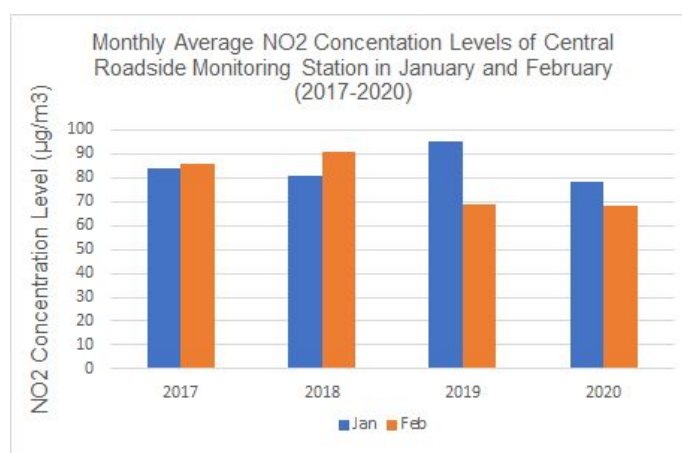
The average NO₂ concentration for 11 spots is 113.5 µg/m³, nearly three times that of the concentration limit stated in the Air Quality Objectives(AQO). This shows that the air pollution is very serious and poses a threat to people's health.



We can observe that the Des Voeux Road Central results in the highest NO₂ concentration, whereas the Queen's Road Central has the lowest NO₂ concentration. This is because there are relatively less bus routes passing through Queen's Road Central. This can also be explained by the traffic condition. According to the AADT 2018, the annual average traffic for Queen's Road Central is around 10,000, one-tenth of that in Des Voeux Road Central. The traffic in Queen's Road Central is much less than that of Des Voeux Road Central, and thus results in a lower NO₂ concentration.

Work-from-home Arrangement and Why it matters?

With the worsening community outbreak of COVID-19 by January 2020, the HKSAR government took the initiative to promote work-from-home arrangement for public servants from government departments, so as encouraging the private companies to follow suit.¹ As a result, we could observe a clear drop in numbers of commuters during rush hours in January and February, as supported by the figures from the Monthly Traffic and Transport Digests released by Transport Department, significant drops in Average Daily Public Transport Passenger Journeys by several public transport operators can be observed, especially for February 2020, almost all major public transport operators, especially those providing commuting service to Central and Sheung Wan, have seen a drop of around 30-50% in passenger journeys, comparing to last year, and also January 2020.² ³ The work-from-home arrangement may have been



¹ [Working from home a new, at times frustrating, experience for some](https://www.scmp.com/news/hong-kong/hong-kong-economy/article/3048557/coronavirus-working-home-novel-occasionally)

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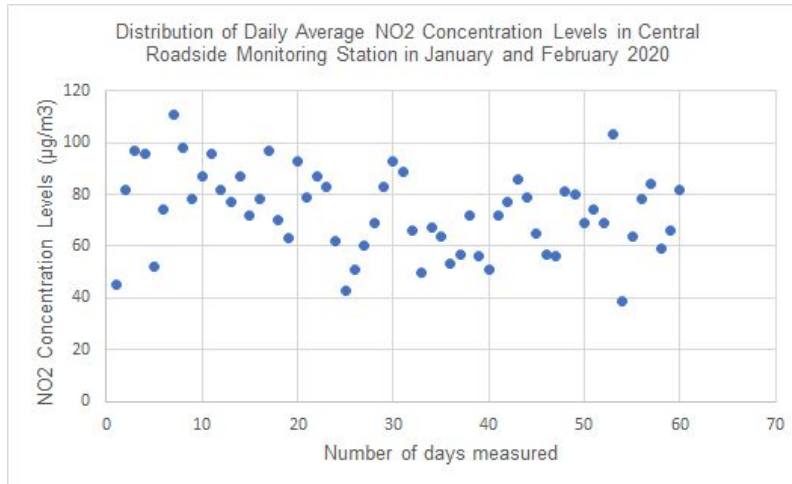
² https://www.td.gov.hk/filemanager/en/content_4970/2001.pdf

³ https://www.td.gov.hk/filemanager/en/content_4971/2002.pdf

vital for reducing the risk of a community outbreak of COVID-19 in Hong Kong, but it is more obvious that such an arrangement will be helpful to lower NO₂ concentration on streets. From the historical data of the Environmental Protection Department's roadside monitoring station in Central, the average daily concentration level in February was 68.1 µg/m³, lower than the measured concentration level of 78.1 µg/m³ in January, so as the measured monthly average concentration levels in past years as shown in the figure.

As Central and Sheung Wan have been one of the busiest commercial districts in Hong Kong, along with several head offices of government departments in proximity, the work-from-home arrangement carried out by public and private sectors has surely contributed to the reduction in commuters using public transport systems, pushing the operators to adjust service accordingly, hence resulting in a decrease in the number of vehicles running on streets. Yet, with fewer cases of COVID-19 in late February, the government departments and most private companies decided to resume work in offices after month-long adoption of the work-from-home arrangement.⁴ Hence, we could expect more vehicles running on streets to satisfy the transportation demands of the commuters for going back to offices, as before the second spike of COVID-19 cases in Hong Kong in late March, NO₂ diffusion tubes were installed on several spots along Des Voeux Road Central, Queens Road Central and Connaught Road Central to measure how the possible increased traffic flow would impact on the concentration level of NO₂ along the three roads, especially during weekdays when higher traffic demands from commuters are observed. As shown in the data measured by NO₂ diffusion tubes, the daily average concentration levels of NO₂ in the measurement spots are mostly all over 100 µg/m³, as calculated from averaging the concentration levels on the weekdays of the 2-week long measurement period.

⁴ [Hong Kong's civil servants to head back to offices from next Monday](https://www.scmp.com/news/hong-kong/health-environment/article/3052335/coronavirus-hong-kong-civil-servants-set-return)
(<https://www.scmp.com/news/hong-kong/health-environment/article/3052335/coronavirus-hong-kong-civil-servants-set-return>)



Comparing with the daily average concentration levels in Central roadside monitoring station measured in January and February by the EPD, it is worth noticing that the work-from-home arrangement since January till late February may contribute to the low concentration levels in Central, as shown from the distribution of most measured daily average NO2 concentration levels, most of the measured concentration levels have scattered between 40 to 80 µg/m3. Such observation may be further solidified when considering the high concentration levels reflected from the result of diffusion tubes set up from early to mid-March, as high concentration levels as shown in last part of this report, may reflect a relationship between the increase in traffic flows after the halt in a work-from-home arrangement, and the rise in concentration levels of NO2 as measured on street levels, especially considering that the diffusion tubes were set up in Queen’s Road Central and Connaught Road Central, where the roadside monitoring station may not be able to cover.

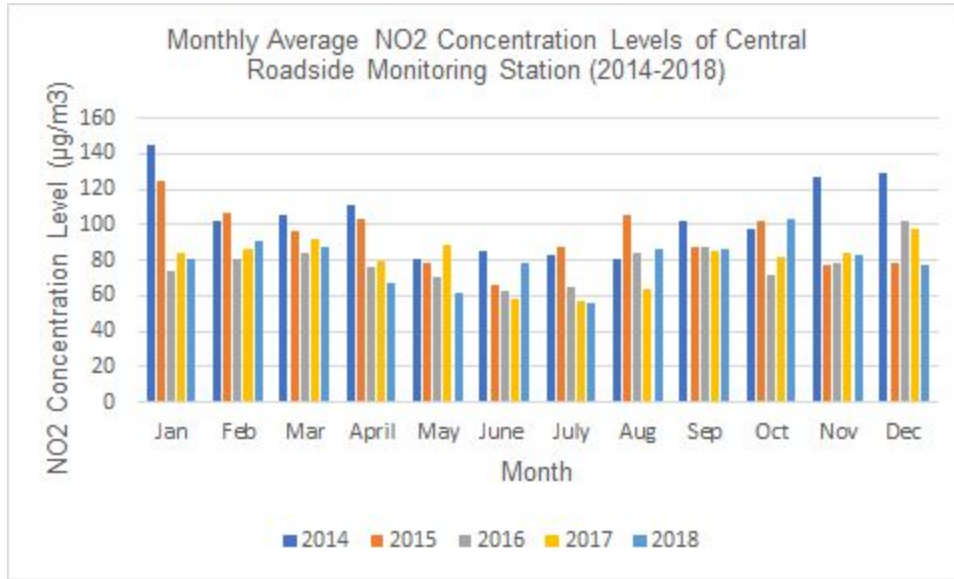
Franchised Bus Low Emission Zones

In Central, Franchised Bus Low Emission Zone has been established since 31st December, 2015, and further tightened to require the three major bus operators to deploy low-emission buses that run on routes passing through the zone, while the buses must meet the emission standard of EURO V or above.⁵ The Franchised Bus Low Emission Zones are set up to tackle the roadside emission of buses, while the established zone in Central covers the intersection of Pedder Street, Chater Road and also part of Des Voeux Road Central, so as including the proximity of Central Roadside

⁵ <https://www.legco.gov.hk/research-publications/english/essentials-1415ise09-low-emission-zone.htm>



Monitoring Station. Under the influence of heavy traffic flow in the intersection and the surrounding high-rise buildings, the air quality in Central had raised public concern, especially when Central has been renowned as the financial hub of Hong Kong, cleaner urban air quality may be vital to attracting foreign investors and protect the health of the commuters, henceforth the government took the initiative to reduce emission from buses by requiring bus operators to deploy bus models which emit fewer air pollutants, such as EURO V or EURO VI in the coming future. From the historical data of Central Roadside Monitoring Station as provided by the EPD, we could see the yearly differences in the monthly averages before and after the establishment of the Franchised Bus Low Emission Zone, which can be expected to be in effect since 2016 for clearer analysis, are showing a correlation between less polluting bus models and reduced NO₂ concentration, while we should also take into consideration that cleaner fuels have also been introduced in Hong Kong for other motor vehicles in recent years, contributing to the reduction in NO₂ from the combustion of motor engines. As a result, in 2016 and years after, the readings from Central Roadside Monitoring Station have been comparatively lower than the years before.



However, from the data obtained from the installed NO2 diffusion tubes, it shows that the established low emission zone may not be absolutely effective in reducing NO2 pollution, as from the installed spot at Landmark Square Bus Stop on Des Voeux Road Central, the result from the installed tubes show that the NO2 concentration problem is still serious, comparing with other spots where NO2 diffusion tubes are installed to measure the concentration during weekdays. Several high readings along the Des Voeux Road Central were also recorded, even slightly exceeding the readings from roads with higher numbers of bus routes passing by, showing that the concentration level of NO2 in Central, despite having great improvement as reflected from yearly data above, is still considerably high and posing potential threats to commuters. The current regulation over the Franchised Bus Low Emission Zone should therefore be tightened to require bus operators to deploy cleaner buses, with purely electric buses being one of the considerable options, in order to offset the pollution from growing numbers of motor vehicles driving within the zones and traffic congestion. As the regulation for the low emission zone requires bus operators to deploy bus models of EURO V or above, while from the EPD's information provided from its proposal to tighten emission standards of first registered bus with design weight not more than 9 tonnes, EURO VI seems to outmatch EURO V in reducing air pollutants, most notably on NOx, but the government should also take the initiative to encourage, or support the bus operators to deploy

	CO 一氧化碳 (mg/kWh)	THC 碳氫化合物 (mg/kWh)	NOx 氮氧化物 (mg/kWh)	PM 可吸入懸浮粒子 (mg/kWh)	PN 粒子數量 (#/kWh)
Euro V 歐五	1,500	460	2,000	20	Not required 不須量度
Euro VI 歐六	1,500	130	400	10	8 x 10 ¹¹
		72% ↓	80% ↓	50% ↓	

Note: Using the emission limit (Compression ignition engine) under WHSC testing cycle for comparison
 註:以排放標準(壓燃式引擎,WHSC測試工況)作比較

electric buses, as a considerable option of bus model that can perform better than EURO V or VI in terms of reducing pollutants during operation. The deployment of electric buses in the Franchised Bus Low Emission Zones can fulfill the regulation of the low emission zone on one hand, and promote Hong Kong as a sustainable city with a clean, futuristic public transportation system to foreign investors on the other hand. ⁶

Electric Bus Route in Central and Sheung Wan

From the last part, the option of deploying electric buses in the Franchised Bus Low Emission Zones is suggested, and from the installation and measurement of NO₂ diffusion tubes along the 3 major roads in Central and Sheung Wan, the results from each street actually provides us with the insight that the commuters, so as the residents on the covered roads, are prone to health risks from NO₂ pollution from motor vehicles passing by, such as cardiovascular and respiratory disease. In fact, Clean Air Network has advocated for more large-scale deployment of electric buses in Hong Kong, as health risks may impact vulnerable groups, such as the children, elderly, chronic patients and the underprivileged heavily, while looking from other megacities' solutions to address roadside air pollution, the transformation of bus fleet to Zero Exhaust Emission technology such as electric/hydrogen is vital to establish Hong Kong's image as sustainable city, so as adopting an innovative solution to address the air pollution from motor vehicles, and helping bus manufacturers to gain valuable experience from deploying electric buses in local landscape.

In recent years, the HKSAR government has implemented several policies to encourage the deployment of electric buses, yet the progress is still lacking behind as less than 1% of the total number of local franchised buses are running on electric, showing that Hong Kong is still comparatively slow than other major cities in China, or countries in Europe. Yet, many may perceive Hong Kong as a challenging ground for deploying electric buses due to the lack of spaces for charging infrastructure and high transportation demand in densely populated urban areas. Central and Sheung Wan, as being densely populated areas with high traffic flows of commercial vehicles, are prone to serious NO₂ pollution and posing great challenges to deployment of electric buses, for example, constant traffic congestion and steep terrains may pose challenges to electric buses, since there will be greater demand for electricity to be stored on the buses' batteries for

⁶ [Euro 6 / VI Implementation in Hong Kong](https://www.epd.gov.hk/epd/sites/default/files/epd/english/environmentinhk/air/prob_solutions/files/Euro%20VI%20Trade%20Consultation%20%28LB%20and%20Bus%29_final_15%20Nov.pdf)

(https://www.epd.gov.hk/epd/sites/default/files/epd/english/environmentinhk/air/prob_solutions/files/Euro%20VI%20Trade%20Consultation%20%28LB%20and%20Bus%29_final_15%20Nov.pdf)

idling in traffic congestion, or climbing up on steep roads. However, with improving battery and charging technology from electric bus manufacturers, electric buses may be able to tackle such challenges with more powerful batteries and adoption of rapid charging during the operation intervals (e.g. before departing from terminuses).

Analysing from the results of NO₂ diffusion tubes measurement and the current bus routes operating in the covered roads of the measurement, bus route 10 operating by Citybus can be a potential choice for deployment of electric buses, as this route provides service to commuters along Des Voeux Road and Queen's Road, so as passing by the Franchised Bus Low Emission Zone. As shown from the results of the NO₂ diffusion tubes, readings from Queens Road and Des Voeux Road are showing that the concentrations of NO₂ are high, as a result of the canyon effect from surrounding tall buildings. From the study conducted by Aerosol and Air Pollution Group of the School of Energy and Environment, City University of Hong Kong back in 2013, finding out that street canyons in urban areas may trap traffic-induced pollutants, while the street canyons of Des Voeux Road and Queens Road significantly restricts the dispersion of traffic emissions from the high traffic flow, causing the concentration levels of NO₂ in these 2 roads to exceed those recorded from Connaught Road, where the traffic flow is the highest among the 3 roads but under less influence of street canyon effect. Moreover, the terminals of bus route 10 are observed to have sufficient space to accommodate charging infrastructure for electric buses, allowing the buses to undergo rapid charging after reaching terminals, in order to meet the high demand from commuters in rush hours.

To address the NO₂ pollution problem, which has been further intensified under street canyon effect to trap NO₂ in densely populated streets, deployment of electric buses on a bus route that provides service on Des Voeux Road and Queen's Road will be vital to address the vehicle pollution problem through reducing emission from buses, taking the initiative to deploy electric buses in a challenging urban landscape and fully utilize the developing technologies to come up with flexible, clean public transportation. Furthermore, the deployment of electric buses in residential and commercial areas can be beneficial to the health of residents and commuters, while it can generate much public awareness by providing the public a new insight into the deployment of new models of electric buses on roads.

Conclusion

NO₂ diffusion tubes have surely been an effective and reasonably-priced option for reflecting street-level NO₂ concentration levels, due to the smaller size and convenience of installation. From the recent measurement on Queen's Road Central, Des Voeux Road Central and Connaught Road Central during weekdays, we can see a trend of relatively high concentration levels of NO₂ in roads with high traffic flows, so as with strong street canyon effect that traps NO₂. Therefore, Clean Air Network will continue to deploy NO₂ diffusion tubes while engaging the community in street measurement programs, while we will also raise public awareness, so as gaining support from stakeholders, on the development of Zero-emission buses, so as the large-scale deployment in Hong Kong, shaping Hong Kong's image as a sustainable city with a clean public transportation system that safeguards the public's health and Hong Kong's clean air.