

Analysis of Impact on Ambient Air Quality of Outdoor Firework Display During Chinese New Year 2013 in Hong Kong

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Abstract: Outdoor displays have been carried out for many years at Victoria Harbour in Hong Kong. These occur at least twice a year on China National Day (CND) and Chinese New Year (CNY) with a show time of about 23 minutes. The 2013 shows attracted many hundreds of thousands of people to watch on both sides of Victoria Harbour for about half an hour. An analysis of the ambient air quality data for 2013 provided by the Hong Kong Environmental Protection Department (HKEPD) was carried out to understand the impact on ambient air quality that may have resulted from the 2013 outdoor fireworks display during the CNY show. The data collected by HKEPD includes carbon monoxide (CO), nitrogen oxide (NO_x), nitrogen dioxide (NO₂), ozone (O₃), respirable suspended particulates (RSP or PM₁₀), fine suspended particulates (FSP or PM_{2.5}), and sulphur dioxide (SO₂). The analysis covers a period of 5 days, 2 days prior to and 2 days after the show during CNY 2013. Due to local air movement from east to west at Victoria Harbour and the high bursting of the fireworks display, the smoke that was generated by the fireworks was quickly dispersed. There was no significant impact on the ambient air quality based on the data collected. A trace of temporary smoke cloud was observed at the bursting height of the firing location.

Introduction

There are many questions concerning air pollution raised by environmental pressure groups, concerning outdoor fireworks. It is predominantly because firework displays generate light and sound that they draw the audience's attention. Some daytime fireworks even produce coloured smokes in the sky to create a colourful sky (rainbow) pattern. The majority of firework displays occur at night with music and different effects such as sparks, brocade, peony, dahlia, waterfall, etc. However these effects are normally accompanied by debris and smoke whether they are intended or not. Many reports^{1,2,3} of the impact of firework displays on air quality have been presented. Debris is created when a paper shell bursts in the air, creating debris or un-burnt paper components or particles and in most cases, they are lightweight and non-hazardous. Smokes are part of the chemical reaction of firework compositions when ignited. The reactions produce different products together with the desired colours of light and sound in its specific chemical reactions, to give a specific effect. The specific effect is the major factor that draws the audience's attention. However the

undesired side products, debris and unexpected smokes, can receive negative comments from the audience, and this is quite common at present. Environmental press groups recommend banning firework displays because of such by-products. On the other hand firework manufacturers have been working towards display fireworks with less visible smoke.

Hong Kong has had firework displays since the 19th century even though there are regulations prohibiting the sale and storage of fireworks. Leaving aside the reason for such prohibitions, fireworks are still one of the most important traditional and cultural items in Hong Kong, an international city whose population is more than 93% Chinese. Outdoor firework displays are therefore allowed on certain special occasions upon permission from a related authority of the Hong Kong government. Although there are small, personally arranged outdoor firework displays, the one organized at Hong Kong Victoria Harbour is the biggest and best-known event in Hong Kong, and probably in the world. A macro analysis of environmental monitoring data collected by the Hong Kong Environmental Department (HKEPD) of the Government of Hong Kong Special

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Administrative Region (HKSAR) around the shooting site was done to investigate the impact on the ambient air quality from this firework display. The data collected by HKEPD include carbon monoxide (CO), nitrogen oxide (NO_x), nitrogen dioxide (NO₂), ozone (O₃), respirable suspended particulates (RSP or PM₁₀), fine suspended particulates (FSP or PM_{2.5}), and sulphur dioxide (SO₂). The analysis covers a period of five days: two days prior to and two days after the show during CNY 2013, which fell on 11 February 2013, as indicated in Tables 1 and 2.

Table 1. Firework display for CNY at Victoria Harbour on February 11, 2013

Event	CNY
Date of display	11 February 2013
Time of display	20:00:00–20:23:06
NEC/kg	4467
Shell calibre/mm (inches)	75–173 (3–7)
Burst height/m	100–200
Weather	East wind 15 km h ⁻¹

Table 2. Weather recorded at Central Pier location (E) by Hong Kong Observatory

Pressure/hPa	1020.0
Air temp./°C	17.2
Dew point/°C	13.8
Relative humidity (%)	80
Wind speed/km h ⁻¹	15
Wind direction/weather	East wind, fine

Outdoor firework displays in Hong Kong

Hong Kong is a small city (1104 square kilometres) of more than 7.15 million people⁴ occupying less than 25% of the developed land of Hong Kong Island, Lantau Island, the Kowloon Peninsula, and the New Territories, including more than 200

outlying islands. Between Hong Kong Island and the Kowloon Peninsula lies Victoria Harbour, one of the world's most renowned deep-water harbours (Figure 1). Since 1967, Hong Kong has prohibited the sale and storage of fireworks. Consumer fireworks cannot therefore be obtained in Hong Kong. Transportation from China to overseas is the biggest channel for exports from China.

Even before the establishment of the Hong Kong SAR in 1997, Hong Kong organized outdoor firework displays in public areas but special permits were required. It is difficult to obtain a permit due to the limited available area (high population density, 6620 people per square kilometre). Hong Kong Disneyland is the only place in Hong Kong currently allowing the firing of 3 inch shells within its premises based on a tight monitoring and control system. There are several other important events or festivals that allow outdoor firework displays performed each year in Hong Kong. These are New Year's Eve celebration, mostly organized at the beginning of the year; the second day of the Chinese New Year (Lunar Year), and China National Day which is October 1. Others were the East Asian Games which were held in 2009 and the 5th, 10th and 15th anniversaries of the establishment of The Government of Hong Kong SAR (handover), of which the latest was held on July 1, 2012.

in order to be able to track the impact of firework displays on the environment, the concentrations of air pollutants for two days prior to and after the display were analysed, making a total of a five day period of data for analysis. This was analysed, in order to evaluate the much longer term impact and to avoid any single and ad hoc weather changing impact. All environmental air pollutants were obtained from HKEPD⁵ which continuously monitors the parameters at 14 monitoring stations. Since firework displays are fired from barges (Figure 2) in Victoria Harbour, the data monitored from the nearest four stations were selected for analysis.

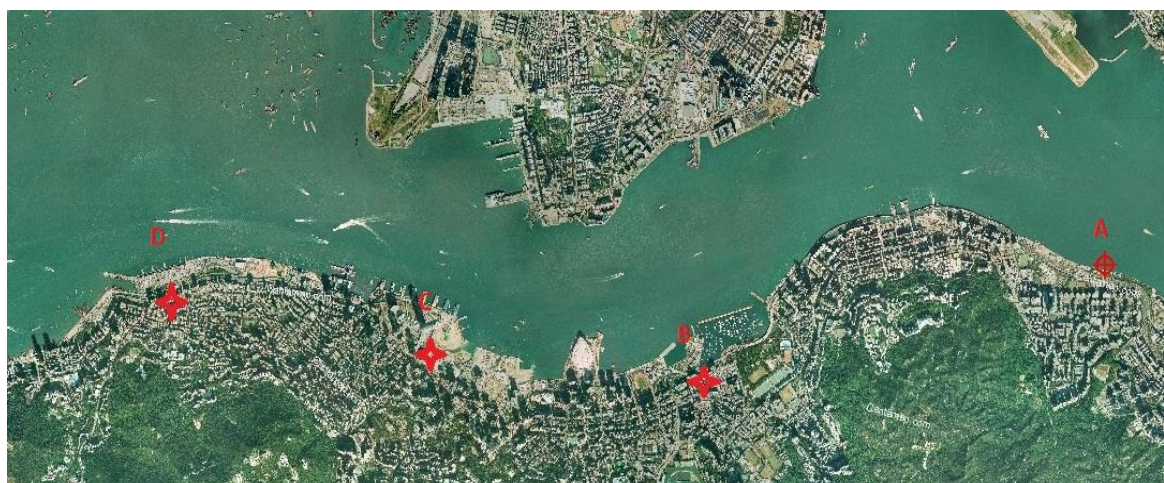


Figure 1. Hong Kong Victoria Harbour and 4 monitoring stations, (A) (right) to (D) (left), source: map from Google

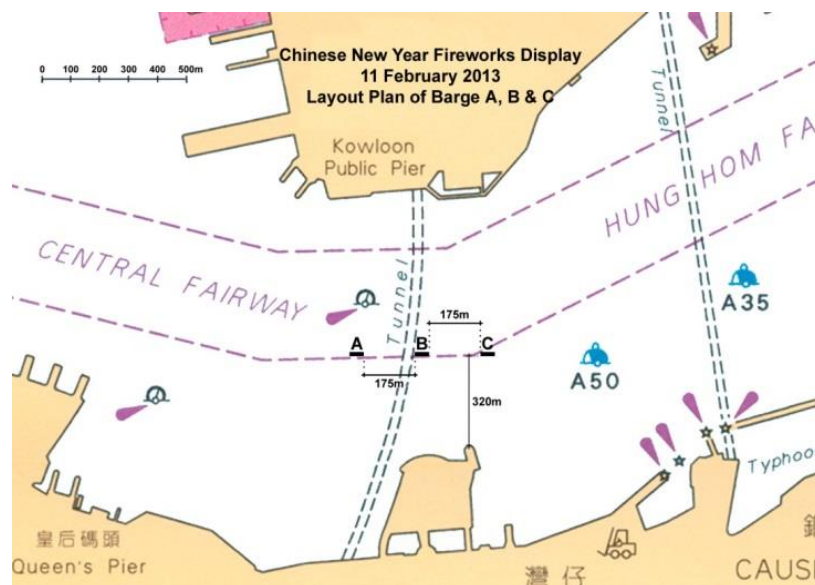


Figure 2. Firework display layout plan of barges A, B and C at Victoria Harbour

These stations are all located on Hong Kong Island and are, from east to west, (A) Eastern Station, (B) Causeway Bay Station, (C) Central Station and (D) Central Western Station, as indicated (right to left) in Figure 1. An observatory station, (E), is used to measure wind speed, relative humidity and temperature at Central Pier, located in the middle of stations (B) and (C), directly adjacent to the shooting site.

Data collected by Hong Kong Environmental Protection Department

The five monitoring stations are located in residential areas at different heights. Some are close to main traffic routes and some are on top of buildings. They are located to represent the best environments for monitoring ambient air without adverse impact from either individual incidence or

personnel interruptions. The exact locations and nearby environments are shown in Figures 3 to 7.

Monitoring stations

(A) Eastern (General Station) – Figure 3

- Location: Sai Wan Ho Fire Station, 20 Wai Hang Street, Eastern, Hong Kong Island
- Sampling Height: 28 meters from sea level
- Distance from shooting site: 3000 metres (approximately)

(B) Causeway Bay (Roadside Station) – Figure 4

- Location: No. 1 Yee Wo Street, Causeway Bay, Hong Kong Island
- Sampling Height: 6.5 meters from sea level
- Distance from shooting site: 800 metres (approximately)

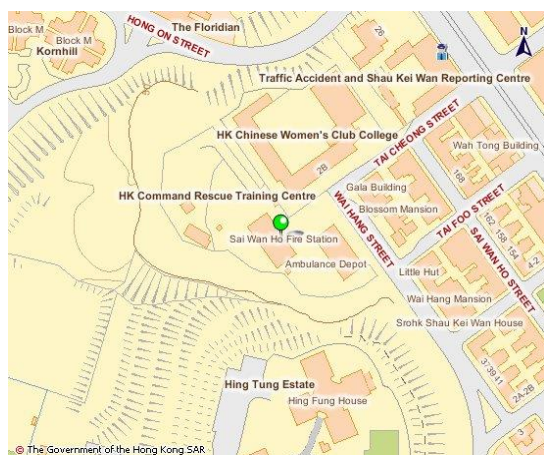


Figure 3. Eastern Station

(C) Central (Roadside Station) – Figure 5

- Location: Junction of Des Voeux Road and Chater Road, Hong Kong Island
- Sampling Height: 8.5 meters from sea level
- Distance from shooting site: 1500 metres (approximately)

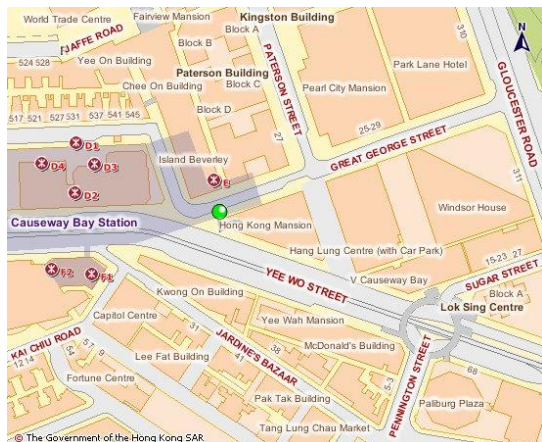


Figure 4. Causeway Bay Station

(D) Central Western (General Station) – Figure 6

- Location: Sai Ying Pun Community Complex, 2 High Street, Central & Western, Hong Kong Island
- Sampling Height: 82 meters from sea level

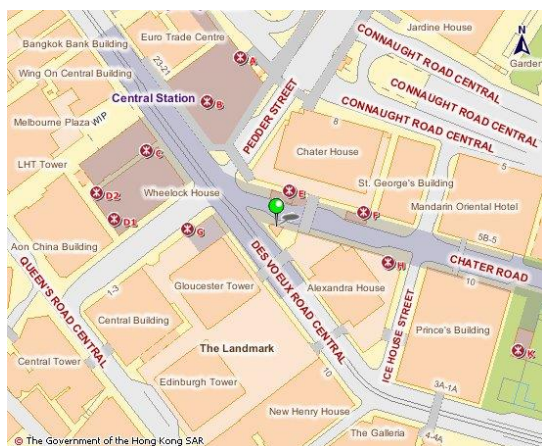


Figure 5. Central Station

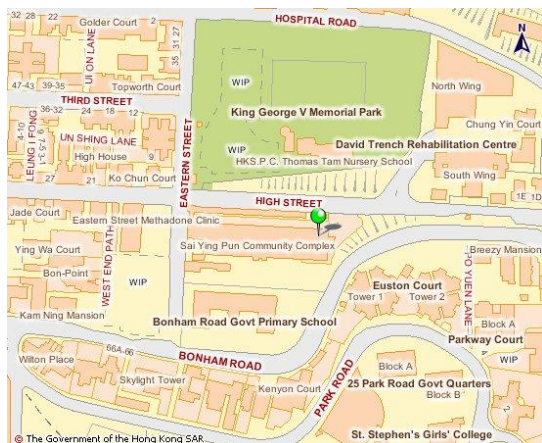


Figure 6. Central Western Station



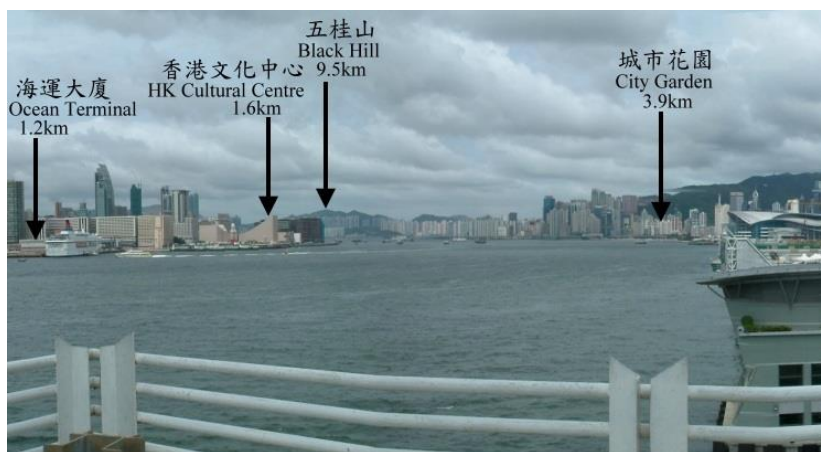


Figure 7. Landmarks viewed from Central Pier pointing to shooting site (east)

- Distance from shooting site: 2000 metres (approximately)

(E) Central Pier – Figure 7

- Location: Latitude N – 22°17'20", Longitude E – 114°09'21", Elevation of ground (above sea level) – 19m
- Address: Pier at the Central District of Hong Kong Island

Key air pollutants

Key air pollutants that were monitored by HKEPD included Respirable Suspended Particulates (RSP or PM₁₀),* Total Suspended Particulates (TSP), nitrogen oxides (NO_x), nitrogen dioxide (NO₂), sulphur dioxide (SO₂), ozone (O₃), carbon monoxide (CO), and later, Fine Suspended Particulates (FSP or PM_{2.5})* were added, which are commonly used as references by other countries such as the European Union, USA, UK, Thailand, etc. They were

monitored from 2005 to date at monitoring stations (A) to (D) (Figure 1), while monitoring point (E) was used for wind speed, temperature measurement and relative humidity. These measuring locations are the closest to the shooting site.

Monitoring equipment used by EPD

Air quality monitoring goes on 24 hours a day, 7 days a week, on average hourly. Most equipment used for gaseous pollutants such as RSP (PM₁₀) and FSP (PM_{2.5}) determines them continuously by automatic analysers. The list of equipment employed for monitoring is summarized in Table 3.⁶

Annual important events

Hong Kong is an international city where multicultural activities are commonly held. With the majority of the population being Chinese, firework displays are common. Besides the two main firework display events in Hong Kong every year (*Chinese New Year (CNY)* – the second day of

Table 3. Equipment being used by HKEPD for measuring ambient air qualities

Pollutants	Measurement principle	Equipment
SO ₂	UV fluorescence	TECO 43A, API 100E, TECO 43I
NO, NO ₂ , NO _x	Chemiluminescence	API 200A
O ₃	UV absorption	API 400, API 400A
SO ₂ , NO ₂ , O ₃	Differential optical absorption spectroscopy	Opsis AR 500 System
CO	Non-dispersive IR absorption with gas filter correlation	TECO 48C, API 300
TSP	Gravimetric	General metal works GS2310
RSP (PM ₁₀)	a) Gravimetric b) Oscillating microbalance	Graseby Andersen PM10 R&P TEOM Series 1400a-AB-PM10 Thermo Scientific TEOM 1405-DF
FSP (PM _{2.5})	a) Gravimetric b) Oscillating microbalance	Thermo Scientific Partisol-Plus 2025 R&P TEOM Series 1400a-AB-PM2.5 Thermo Scientific TEOM 1405-DF

the Lunar Year (Chinese New Year) which is always either in January or February of the year and *China National Day (CND)* – October 1) there are some other irregular or less frequent firework display events such as the East Asian Games, celebration of Tsing Ma Bridge, etc. For the sake of continuity and repeatable measurements, the analysis includes the CNY and CND only.

Discussion

The outdoor firework display was performed at 20:00. It was fired at Victoria Harbour, the deepest bay of Hong Kong between Kowloon Peninsula and Hong Kong Island because the shooting site is large with a sufficient safety zone. The show could be seen along both sides of the harbour. In fact the HK firework display at Chinese New Year has become a tourist attraction. It was attended by about 300 000 to 600 000 people standing on both sides of the harbour. The distance between both sides of the harbour is about 1000 m. The location provides a clear safe zone when marine control of boats is enforced during the show. The mortar racks were installed on the barges A, B and C. (Sometimes there may be 4 to 5 barges depending on the scale of the show.) These barges were then brought to the designated location (Figure 2), and anchored. The display was of 23 minutes 6 seconds duration. During the performance there were 12 themes playing continuously and synchronized fireworks launching with music or songs.

During the show, as normal, there were smokes and debris produced at around 100 to 200 meters height above sea level because 90% of the fireworks used were cakes and aerial shells fired from the barges. Fireworks fired at water level were seldom used due to the water surface not being still and the long distance view from both sides of the harbour. The pollutant monitoring data were extracted for a period of five days, i.e. two days before the display and two days after, to show the continuation of the background level. Therefore there were five consecutive days of data (or 120 hours) showing the

ambient air quality at the four stations (A) to (D). The wind speed, temperature and relative humidity were obtained from the HK Observatory. This was used to compare the effects of weather changes, if any.

Since the show took place at 20:00 on February 11, 2013, the monitoring pollutant data are shown at the 68th hour in all parts of Figure 8. There are four charts marked from (A) to (D) indicating the monitoring station location, East to West. The red arrow indicates the exact the time of the performance in charts (B) and (C) which were the nearest stations to the firework display. The weather conditions such as temperature, relative humidity and wind speed were recorded at the nearest location (E), Central Pier by Hong Kong Observatory,⁷ and are shown in Table 2.

Analysis of individual outdoor firework displays

The monitoring data of all key pollutants at stations (A), (B), (C) and (D) during CNY 2013 are shown in Figure 8. These pollutants were sulphur dioxide (SO₂), Respirable Suspended Particulates (RSP or PM₁₀), Fine Suspended Particulates (FSP or PM_{2.5}), nitrogen oxides (NO_x), nitrogen dioxide (NO₂), carbon monoxide (CO), and ozone (O₃). All units of measurement are $\mu\text{g m}^{-3}$ except for CO which is 10 $\mu\text{g m}^{-3}$. Some data were missed due to mechanical breakdown. The red arrow indicates the time the performance started.

Chinese New Year (CNY) 2013

The five days of pollutant data are shown in Figure 8, from February 9 to 13, 2013 (120 hours, Sunday to Thursday) with the display performed on February 11, 2013 (Tuesday) at 20:00 for a period of 23 minutes 6 seconds (show time at the 68th hour on x-axis). The measured data recorded at stations (A) and (D) are flat and low meaning that pollutants were low and normal. This was because these two stations were far away from the central area where the densest population and commercial activities

Table 4. Hong Kong Air Quality Objectives (AQOs)⁸

Pollutant/ $\mu\text{g m}^{-3}$	Average time				
	1 hour	8 hours	24 hours	3 months	1 year
Sulphur dioxide (SO ₂)	800		350		80
Total suspended particulates (TSP)			260		80
Respirable suspended particulates (RSP or PM ₁₀)			180		55
Nitrogen dioxide (NO ₂)	300		150		80
Carbon monoxide (CO)	30 000	10 000			
Ozone (O ₃)	240				
Lead (Pb)				1.5	

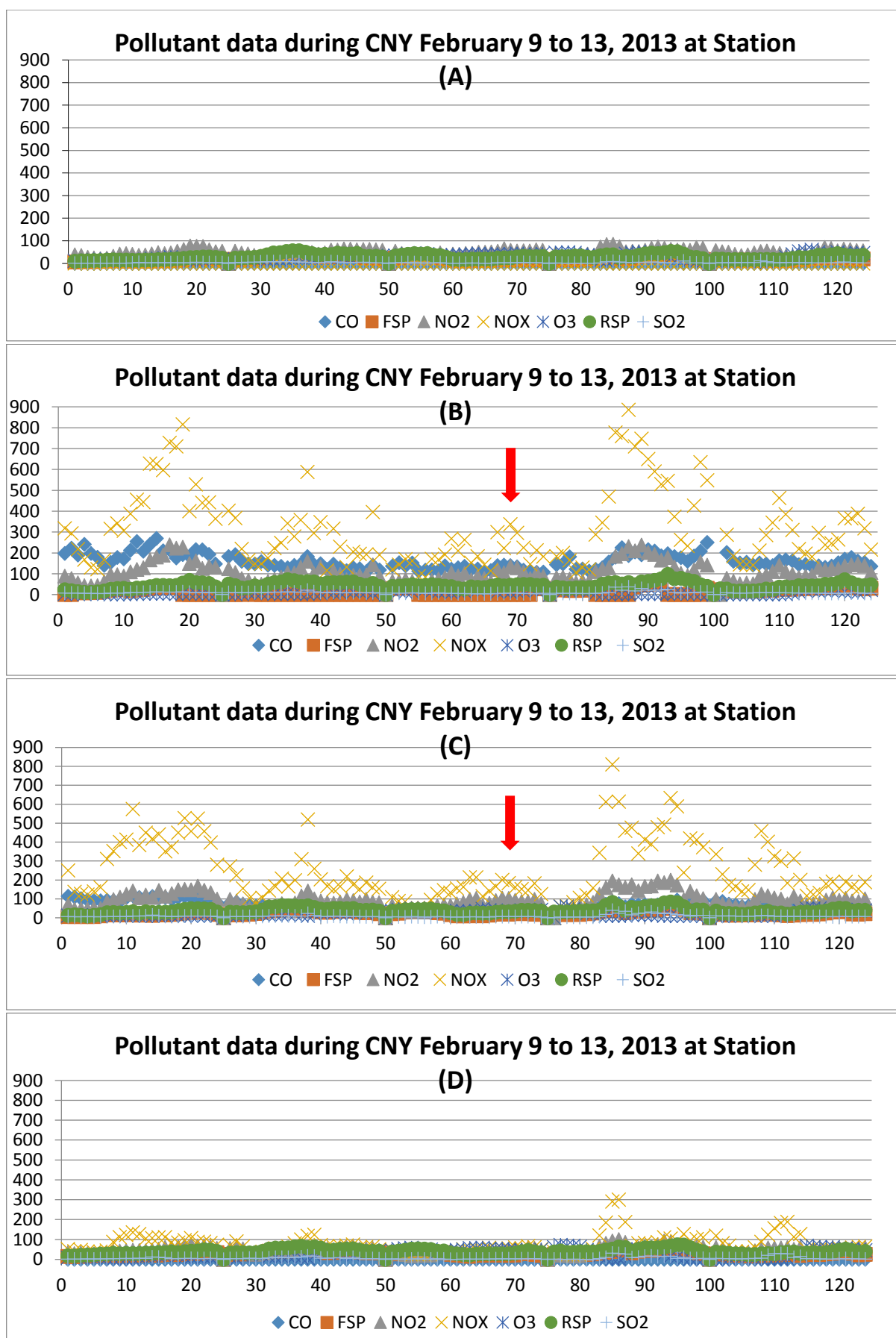


Figure 8. Pollutant data during CNY February 9 to 13 at Stations (A) to (D) (top to bottom). All units of measurement are $\mu\text{g m}^{-3}$ except for CO which is $10 \mu\text{g m}^{-3}$.

Table 5. Highest hourly pollutant concentrations measured in Hong Kong 2013

Pollutant, ($\mu\text{g}/\text{m}^3$)	AQO / 1 hour	Highest hourly pollutant at Stations			
		A	B	C	D
Sulphur dioxide (SO_2)	800	89	105	133	200
Total suspended particulates (TSP)		NA	NA	NA	NA
Respirable suspended particulates (RSP or PM_{10})		251	227	252	180
Fine suspended particulates (FSP or $\text{PM}_{2.5}$)		128	175	155	198
Nitrogen dioxide (NO_2)	300	230	454	468	266
Nitric oxide (NO_x)		NA	824	1025	545
Nitrogen oxide (NO)		NA	1570	1899	1030
Carbon monoxide (CO)	30 000	NA	4070	2680	NA
Ozone (O_3)	240	192	120	124	258
Lead (Pb)		NA	NA	1.5	NA

were. From stations (B) and (C), the two stations located at the local commercial and shopping district, the data show larger variation. However the charts showed an increase of pollutants from the 35th hour but not at the 68th to 69th hour when the firework display was performed.

The wind speed was 15 km h^{-1} blowing from east to west. The chart for station (D) which was in the downwind direction did not show visible smoke nor any adverse effect at or after the 69th hour.

As shown in Table 4, there are key pollutant monitoring data for the whole year in Hong Kong before 2014. This is an average of measurements all around the areas (14 monitoring stations) measured in Hong Kong. It showed the firework display at CNY 2013 did not have any adverse effect on ambient air quality.

The highest hourly pollutant concentrations measured in 2013 are shown in Table 5. This was

the highest hourly data among all measurements in Hong Kong for the whole of 2013. When looking at the stations (B) and (C) in Figure 8 while the firework display was going on at 20:00, February 11, 2013, the key pollutant measurements are all below the highest record for the year. From the other point of view, the highest hourly pollutant data in Table 5 were not caused by the firework display events at CNY.

Conclusions and recommendations

The impact on ambient air quality was negligible for firework displays during CNY 2013 in Hong Kong. Analysis of ambient air quality around the shooting site was very similar to that for the previous four years (2010 to 2013).⁹ The changes in key air pollutants are shown in Table 6. One could argue that the monitoring data were not specific to the



Figure 9. 2013 Fireworks Display at Victoria Harbour of Hong Kong

Table 6. *Changes of concentration levels of key air pollutants from 2010 to 2013 of Hong Kong*

Pollutant, $\mu\text{g m}^{-3}$	*	2013	2012	2011	2010
RSP (PM ₁₀)	G	50	42	48	45
	R	56	53	61	60
FSP (PM _{2.5})	G	32	28	34	29
	R	37	33	39	36
NO _x	G	110	90	91	94
	R	320	312	326	318
NO ₂	G	60	51	53	52
	R	120	119	122	117
SO ₂	G	12	11	13	12
	R	11	10	12	10
O ₃	G	30	40	41	39
CO	G	850	733	669	693
	R	950	1011	955	1066

firework display because the data were not good enough. However the ambient air quality was also affected by many factors such as transportation, population, wind direction, wind speed, humidity, etc. It was not possible to isolate the firework display factor and conclude there was an impact by shooting fireworks. Furthermore the public showed more interest in the change in measured data regarding ambient air quality. So using this analysis could possibly reflect that there was negligible impact on the surroundings.

From Figure 8, there was another observation from stations (B) and (C) which were close to the shooting site and to a busy shopping area. The background ambient air pollutant level was already high compared to stations (A) and (D) throughout the five days monitored. When compared to national requirements, the quality was acceptable.

Lastly and most important, the right selection and management of the firing site is a critical factor. Hong Kong Victoria Harbour (Figure 9) is an excellent venue for firework displays. The buildings located on both sides of the harbour provide a good viewing location and an excellent air cleaning pathway. For this reason the impact on ambient air from the display was acceptable. However this was a local case study and it does not imply all displays would have similar observations. It would be worth comparing in detail with more specific measurement data. However with thoughtful and careful planning of firework displays, the positive contribution from firework displays to society and the public is far greater than the negative one.

Notes

*RSP (PM₁₀) refers to respiratory suspended particulates having particle sizes equal to or less than 10 microns. FSP (PM_{2.5}) refers to the fine

suspended particulates having particle sizes equal to or less than 2.5 microns.

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