

Keeping Indoor Air Clean from Smoke During Big Fires in Downtown Areas

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Abstract

Smoke emitted from city fires taking a long time to suppress affects indoor air quality (IAQ) of adjacent residential areas. Several such big fires occurred in downtown Hong Kong including the one with vast amount of smoke emitted for 15 hours from a ship fire in harbour, June 2022. Portable air cleaners might be a solution for big houses with storage space for such equipment in countryside. However, in Asia-Oceania dense urban areas with small residential buildings and even subdivided units, residents have no space to store the portable cleaners. Further, their effectiveness in those crowded spaces to watch. For gathering areas in crowded spaces, operating the dynamic smoke control system, if available, could be a solution.

1. Introduction

Big fires taking a long time to suppress in urban areas gave challenges on indoor air quality (IAQ) [1,2]. This refers to big fires in urban areas [3-12], particularly those in Asia-Oceania (AO) city clusters. There were ship fires in June 2021 [3], and temporary accommodation unit fire under highway bridge in April 2022 in Hong Kong [6,13] as shown in Figs. 1 and 2. There were several big fires and even explosions from renewable energy buses and explosion due to collision of heavy goods vehicles in August 2022 in China [10,12] as in Fig. 3. Although burning occurred in small areas, smoke affected millions of people. On the other hand, there are also concerns on wildfires in remote areas, affecting only a small number of people [14,15] but burning large areas.

2. Two Scenarios

Smoke generated by big city fires would affect IAQ for a duration of 1 or 2 days. In the first example [3] of Hong Kong, over 0.2 million of people living at the southwestern side of the harbour were affected for a day. That fire had small burning areas but huge volume of smoke emitted with unknown toxicity. Other fires emitting huge amount of smoke in dense urban area

[10-12] have similar consequences. The toxicity potency is unknown because only gas species in limited number of monitoring stations were recorded by the government Environmental Protection Department.

On the other hand, wildfires burnt in huge areas with much higher heat release rates in weeks. Those areas were not densely populated. Houses were subjected to strong thermal radiation emitted by huge fire. Occupants must evacuate instead of staying there and wasting resources in keeping IAQ is irrational. The house might only be able to resist 4 hours of fire [16], but the fire lasted for weeks! But situation at urban areas is entirely different: IAQ must be kept to a reasonable level. People might find ways (or trained beforehand if there is good forest management as the former US President Trump suggested [17-19]) to evacuate.

Taking Hong Kong as an example, three such big fires occurred within two weeks in 2021 on ship, yacht and waste collection station [1]. Vast amount of smoke was emitted from the burning ship for 15 hours, affecting citizens around the harbour area.

3. Smoke Extraction

As in protecting building occupants from smoke during wildfire [14,15] or others [20], occupants are protected from smoke coming from outside. Effects of smoke emitted on IAQ should be watched. It is important to keep IAQ at an acceptable level.

Extracting smoke spread from outside the buildings by the installed mechanical ventilation system to control IAQ might not be appropriate. The normal filtering system of the mechanical ventilation system will be contaminated quickly. Recirculating the air will spread smoke to other zones of the buildings.

Earlier studies with examples presented in some studies [15] found that portable air cleaners with high-efficiency particulate air (HEPA) filtration were successful in reducing the PM_{2.5}. However, spaces are limited in small units to keep such portable cleaners. Consequently, they are not found in many buildings, in particular, subdivided units [21] of old residential buildings relying on natural ventilation [22]. They have no space for installing air-conditioning system.

4. Using Smoke Management System in Big Buildings

Adopting the Smoke Management System (SMS) [23,24] installed in big buildings, if available, is another choice. As explained, turbulent air flow in a fire generated will drive smoke quickly up by buoyancy as an axisymmetric plume, forming a ceiling jet and then a stable smoke layer

[16]. SMS is activated to remove hot smoke by natural vents, or by mechanical fans and ducts.

However, air contaminated by outdoor smoke is not so hot as fire-generated smoke. Natural vents [25] cannot remove contaminated air due to the low buoyancy. A feasible solution at the moment is to operate the mechanical smoke extraction system [26-29]. Appropriate facilities management has to be worked out for better utilizing the common smoke extraction rate of 8 air changes per hour.

5. Other Concerns

There were some recommendations [15] on handling smoke driven by wildland urban interface with huge country fires polluting IAQ. Using air filtration [15] with portable air cleaners might be a solution during highly polluted days, although the effectiveness is yet to watch. However, the big fires inside dense urban areas should be watched. There are other unexpected pollution sources:

- Big full-scale fire experiments [2] emitting large quantity of smoke from fire laboratories in areas near residential areas led to legal responsibility.
- Discharging tear gas bombs inside buildings including subway stations [20].
- The potential danger on keeping large number of fuel and gas tanks while developing urban areas such as Tsing Yi Island [30,31] should be watched.
- There are many other complaints on contaminated kitchen extraction air from catering services with Chinese food cooking.

Anyway, there will be more expectations from ventilation engineers to provide a safe and healthy indoor environment. Efforts to provide guidance for commercial buildings on protecting occupants from smoke during big fires including at wildland interface in dense urban areas [32-34].

6. Conclusions

There are concerns on modern city fires with new ignition sources, such as renewal energy as fuel cell and electric vehicles, with so many fires with public buses using renewable energy caught fire by itself under a bridge as shown in Fig. 3. Big fires occur downtown would affect millions of people, because they live closer together. This is much more dangerous than those wildfires because of IAQ problem. For crowded areas, dynamic smoke control is the key.

IAQ should be kept to an acceptable level at AO city cluster in big urban fires. People there are living so close to the fire emitting huge smoke volume, small heat and relatively shorter

burning duration of a few days. Houses at Wild Urban Interfaces might be exposed to big fire of high heat released lasting for weeks but affecting not so many people. More importantly, they can evacuate by driving their cars out, very different from those stayed in a subdivided unit of old tall building with inadequate egress. An appropriate fire action plan is to evacuate, rather than staying inside for a long time. Keeping IAQ acceptance within the fire resistance period is more than adequate. Further, where is the space storing such air cleaner? Perhaps, enhancing fire safety management as proposed by President Trump years ago is a good solution.

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Fig. 1: Fire under bridge, April 2022



(Hong Kong Fire Services Department Facebook. <https://zh-hk.facebook.com/hkfsd.gov.hk/>)

(a) Firefighting



(b) Smoke spread out

Fig. 2: Burning temporary accommodation units of construction site, September 2022



(“Public bus on fire in Haikou”, Video from WeChat. Channels (Kao Shan Tun Xian Hua), 29 August 2022)

(a) Clean energy bus caught fire under bridge after explosion, Haikou, Hainan, China



(“Fire in Hefei”. Video from WeChat. Channels (Kao Shan Tun Xian Hua), 21 September 2022)



(“Fire at the China Telecom Building in Changsha, Hunan on 16 September 2022”. Video from WeChat. Channels (Kao Shan Tun Xian Hua))

(b) Explosion of HGV in Hefei, Anhui, China (c) Burning building, Changsha, Hunan, China

Fig. 3: Three burning fires in China