SFDPH Environmental HEALTH
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SAN FRANCISCO
PLANNING DEPARTMENT

Building Height Fact Sheet
Article 38 of the San Francisco Health Code
Requires Enhanced Ventilation for all units in a building

Research is conclusive that those living near busy freeways and roadways have poorer health outcomes than those living elsewhere. In 2008, San Francisco Health Code (HC) Article 38 was adopted to require new residential construction projects located in identified potential roadway exposure zone to install enhanced ventilation if modeling results showed that the property was in an area where PM2.5 from roadway pollutants would be excessive. Article 38 states that those buildings requiring enhanced ventilation "design a system capable of removing>80% of ambient PM2.5 from habitable areas of dwelling units".

Article 38 requires that enhanced ventilation be provided to **all** units in a building, even those on the upper floors. The reasons for this may not be intuitive, however, there is compelling evidence that outdoor air quality at higher elevations is ***not*** consistently improved over air quality at street level. The presence of adjacent buildings and urban canyons cause irregular flow fields and vertical mixing; furthermore, the configuration of adjacent structures can change over time. In addition, urban areas have increased mechanically generated turbulence from vehicles, especially in close proximity to roadways. Because outdoor air quality in Air Pollutant Exposure Zone is unpredictable and likely to be unhealthful at high elevations above street level, the law requires enhanced ventilation for all dwelling units, including those located in upper floors of high-rise buildings.

This table summarizes select findings of reliable research; additional details including full citations are below. These studies are consistent in demonstrating that it is not unique for pollutants from nearby roadway and ground-level sources to reach all floors and sides of high-rise buildings. Furthermore, in a densely populated area such as San Francisco, unpredictable wind patterns and other meteorological conditions make it nearly impossible to ensure that pollutants from ground level sources will never affect specific residential units within a building.

Research Information	Selected Results	Source*
Vertical profiles taken from an 11 story building near two above-ground highways	Particle number concentrations (PNC) and particulate matter less than 2.5 µm (PM2.5) did not show a significant change (neither increase nor decrease) above street level	Wu et al., 2013
Particulate data collected from multiple heights around 3 buildings by busy roadways.	Data were not overwhelmingly supportive of any consistent vertical behavior patterns near tall buildings.	Quang et al., 2012
Polycyclic aromatic hydrocarbons (PAH), black carbon, and PM2.5 were measured at 3 different floor levels in a dense urban area	Outdoors, the highest median levels were observed at 3rd–5th FL for all measured air pollutants, although the trend was not statistically significant and variability was observed at all heights	Jung et al., 2011
Dispersion of particulate matter around low- and high-rise buildings near busy roadways was evaluated on all sides of the building envelope.	At the side and rear of one of the high rise buildings concentration of sub-micrometer particles increased with height.	Hitchins et al., 2002
***Complete citations and additional details are below.**		

In addition to the above selection of specific studies, in 2012 the **California Air Resources Board** published a review of scientific research entitled "*Status of research on potential mitigation concepts to reduce exposure to nearby traffic pollution*" which included the conclusions that **housing sensitive populations in higher floors of buildings cannot currently be considered a reliable mitigation effort to reduce exposures from nearby roadways. The report also found that differences in PM concentration with height can depend heavily on local meteorological conditions and surrounding building geometry**. Air Resources Board (ARB). Status of research on potential mitigation concepts to reduce exposure to nearby traffic pollution. California Environmental Protection Agency. (2012)

Hitchins, J., Morawska, L., Gilbert, D., Jamriska, M. *Dispersion of particles from vehicle emissions around high- and low-rise buildings*. Indoor Air. 12(1): 64-71. (2002)

Setting: Three buildings in Australia were included in the vertical profile measurements: Two high rise buildings office buildings located at distances of 15 and 80 m from a major road, and a third multi-story car park located 5 m from a major road.

Methods: Concentration of sub-micrometer particles were measured at different elevations at the front of each of the high-rise buildings, and on the side and rear of one of the buildings. Results were reported as Normalized Total Number Concentration (%)

Select Results:

Normalized Total Number Concentration (%) at the Rear of an Office Building 80 meters from Roadway

Height	0 meters	9 meters	24 meters
Normalized Total Number Concentration (%)	102%	110%	150%

A decrease in concentration of sub-micrometer particles with respect to height was observed for measurements taken in the front of the building. However, measurements taken on the side and rear of the building showed an increase in concentration of submicrometre particles with height. This increase was likely due to the presence of buildings in close proximity affecting wind flow and the vertical dispersion of particles.

Jung, K., Bernabe, K., Moors, K., Yan, B., Chillrud, S., Whyatt, R., Camaan, D., Kinney, P., Perera, F., Miller, R. *Effects of floor level and building type on residential levels of outdoor and indoor polycyclic aromatic hydrocarbons, black carbon, and particulate matter in New York City*. Atmosphere. 2: 96-109. (2011)

Setting: Part of an epidemiologic study of the relationship between traffic pollution and asthma in New York City 2005-2006

Methods: Polycyclic aromatic hydrocarbons (PAH), black carbon, and PM2.5 were measured in 1/3 of selected participant's buildings at heights up to the 32^{nd} floor.

Select Results:

Floor	0-2	3-5	6-32
Number of samples	32	47	19
PAH nonvolatile	1.58	1.74	1.48
PAH semivolatile	13.5	16.4	13.4
Black Carbon	1.54	1.65	1.36
PM2.5	10.6	11.6	10.2

Researchers noted that the high rise buildings in their study were in public housing complexes, which compared to mid-rise buildings in the study, were a greater distance from roadways and commercial spaces and nearby neighborhoods, and closer to open green space, facilitating vertical mixing, dilution and dispersion of air pollution.

Quang, T., He, C., Morawska, L., Knibbs, L., Falk, M. *Vertical particle concentration profiles around urban office buildings*. Atmospheric Chemistry and Physics. 12: 5017-5030. (2012)

Setting: rooftop and street levels of three urban office buildings in Brisbane Australia 2009-2010

Methods: concentrations of Particle Number (PN) and PM2.5 were taken in each building by simultaneous measurements

Building A: 17m height, 7m from 900 bus/day bus-only roadway.

Building B: 77m height, surrounded by other high rise buildings; proximal to 11,000 vehicles per day roadways.

Building C: 25m height, 7m from 110,000 vehicles/day freeway.

Select Results:

Building C Morning rush hour during non-nucleation events

	Street Level	Rooftop Level
Particle Number	12.48 ± 1.21 ($\times 10^3$ cm^{-3})	18.64 ± 1.21 ($\times 10^3$ cm^{-3})
PM2.5	17.70 ± 0.79	19.00 ± 0.51

PM2.5 levels, particle number size distribution and particle number did not vary consistently with height among the three buildings. For PM2.5, during Non-nucleation events: PM 2.5 levels at Buildings A and B were lower at rooftop compared to street level, while Building C had higher levels. During nucleation events PM2.5 was always lower at rooftop whereas the levels of particles less than 30 nanometers were consistently higher at rooftop compared to street level.

Wu, C., MacNaughton, P., Melly, S., Lane, K., Adamkiewicz, G., Durant, J., Brugge, D., Spengler, J. *Mapping the vertical distribution of population and particulate air pollution in a near–highway urban neighborhood: Implications for exposure assessment*. Journal of Exposure Science and Environmental Epidemiology. (2013)

Setting: 11 story building <400 m from 2 above-ground highways in Boston, MA.

Methods: Vertical profiles were collected at 10 cm/s on seven Fridays in morning (0900 to 1100), afternoon (1200 to 1500), and evening (1600 to 1800) from November 2011 to March 2012. A total of 23 profiles were averaged.

Select Results:

	Below Floor 2:	Above Floor Seven:
PM2.5	7.9 ± 0.66	7.5 ± 0.66
Particle Number Concentration	$37{,}000 \pm 6800$	$41{,}000 \pm 4600/cm^3$

The authors' conclusions included that more mixing and less pronounced concentration gradients will occur within the scale height of buildings in a city. This study showed that ground-based measures of Particle Number Concentration are unchanged approximately six stories above ground, and suggested that additional research is needed to improve our understanding of the temporal and spatial variation of PM with elevation.