Tunnel Ventilation

International Practices for Road Tunnels

Purposes of Tunnel Ventilation

- Maintain acceptable air quality
  - Carbon Monoxide (CO) : 70ppm – 90ppm
  - Nitrogen Dioxide (NO_2) : 0.4ppm – 1ppm
  - Extinction Coefficient : 0.005/m – 0.009/m (Visibility)
- Smoke management for fire incidents

Tunnel Ventilation Methods

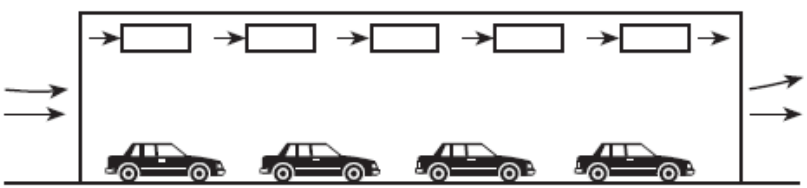
Normal Operation

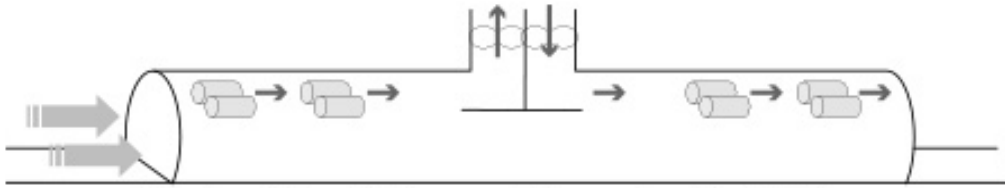
- Dilution
  Introduce sufficient fresh air to dilution the pollution level

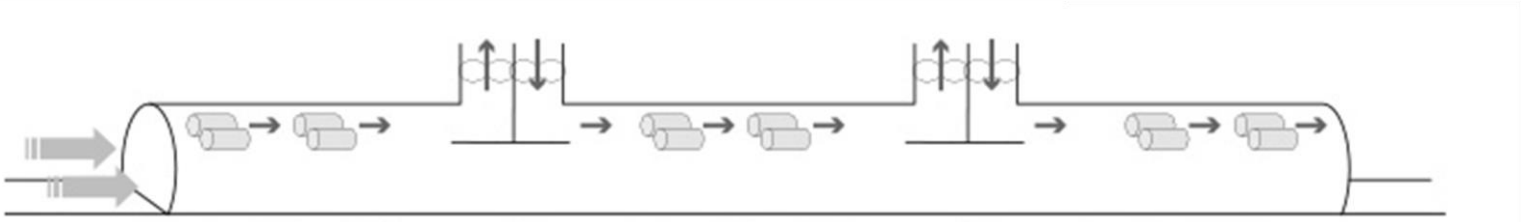
- Filtration (not cover in this presentation)
  Provide filtration plant (i.e. active carbon filters, cold plasma, Electrostatic precipitator (ESP)) to take out CO, NO_2 and PM

Ventilation Systems Longitudinal

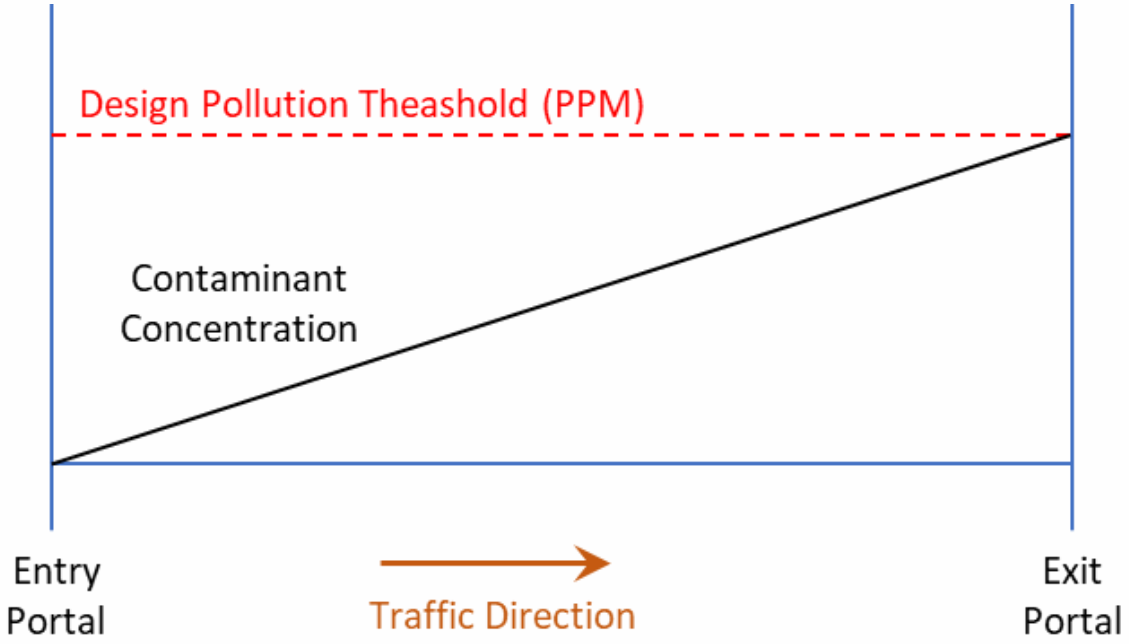
- Air travelling longitudinally in the tunnel
- Air velocity stays constant from the starting point to the end point of the ventilation zone







Ventilation Systems Longitudinal

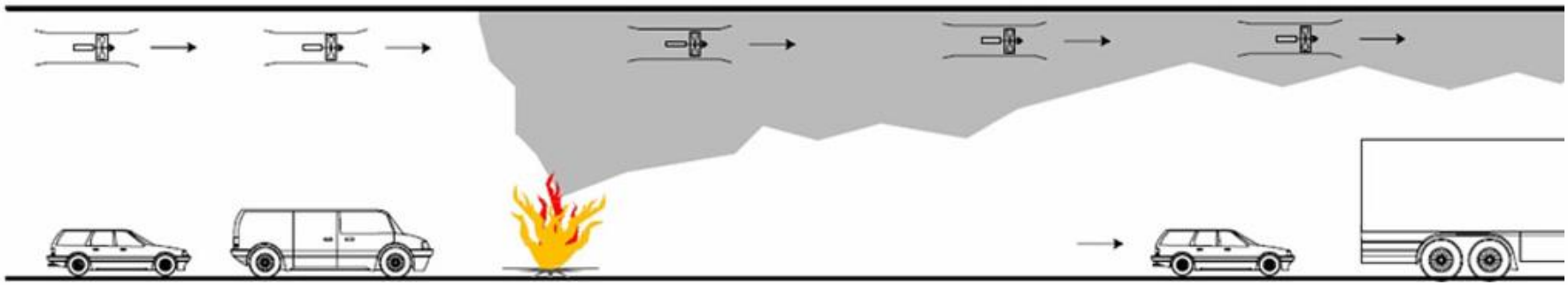


Typical In-Tunnel Air Quality Chart

Ventilation Systems Longitudinal

Fire Emergency Operation

- Ventilation direction follows traffic direction based on the assumption that the down stream traffic is smooth with no traffic jam.
- Averaged tunnel air velocity at the upstream shall be higher than the “Critical Velocity”.



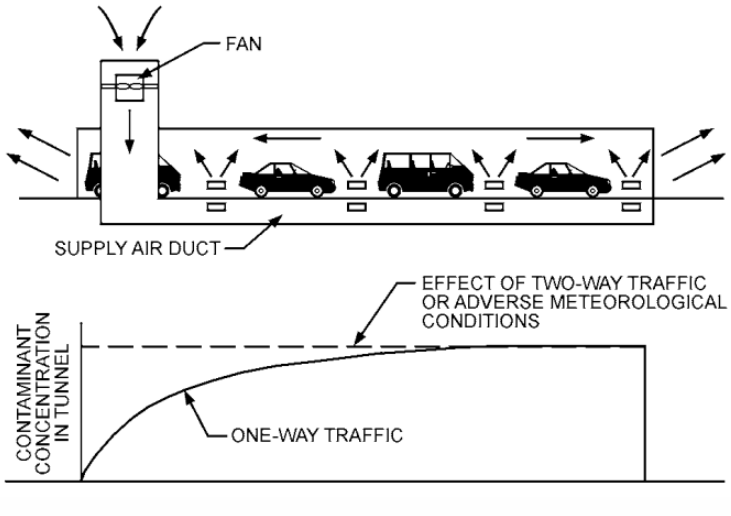
Ventilation Systems Longitudinal

Pros and Cons

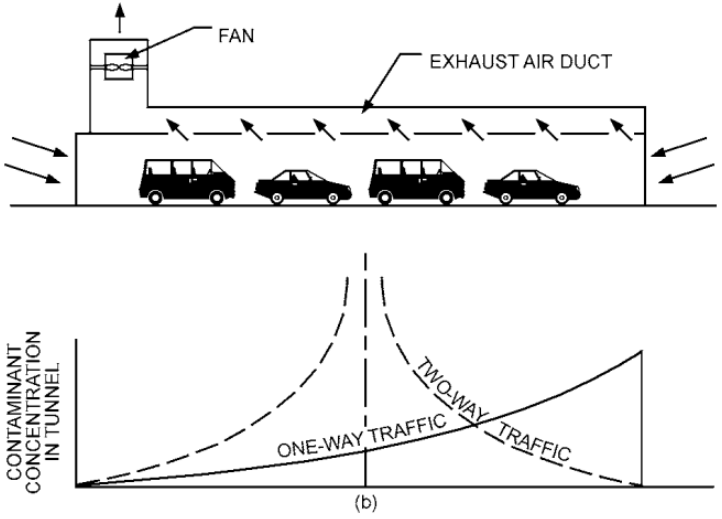
- Able to handle high fire Heat Release Rate (HRR).
- Very efficient for normal ventilation as all the fresh air will be used for pollution dilution.
- High energy efficiency as the traffic can help to ventilate the tunnel.
- Low civil and structural requirements.
- Maximum airflow rate is limited by tunnel cross sectional area (usually <11m/s). May not suitable for very long tunnels.
- Not suitable for bi-directional traffic on fire safety concerns.
- If the fire happens at the starting point of a long ventilation zone, the equipment on the downstream of the fire could be damaged. The refurbishment costs and time would be very high.

Ventilation Systems Transverse

- Air travelling transversally in the tunnel

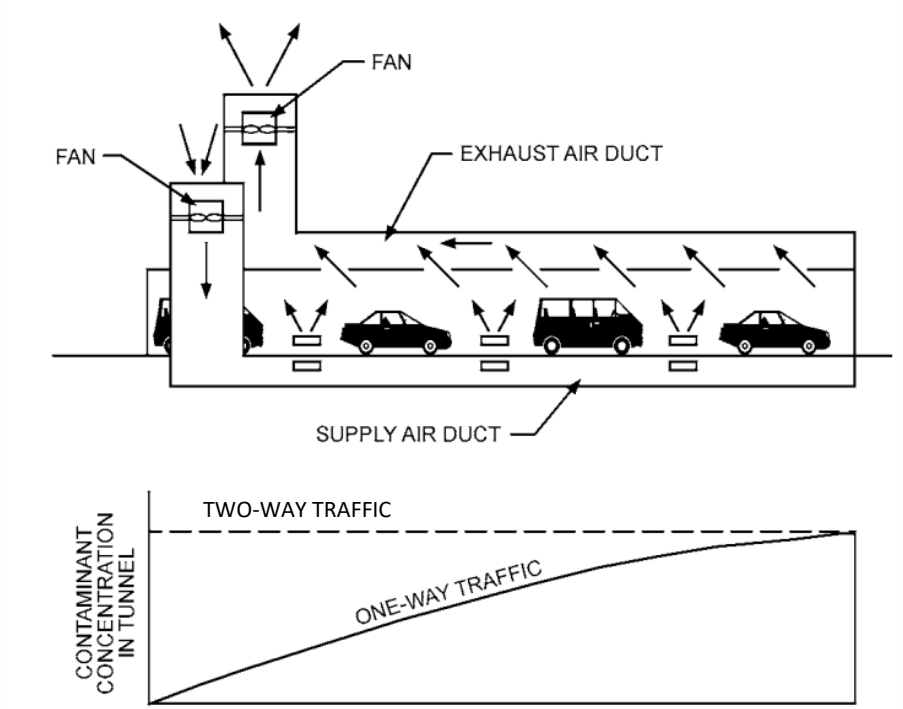


Semi-Transverse (Supply)



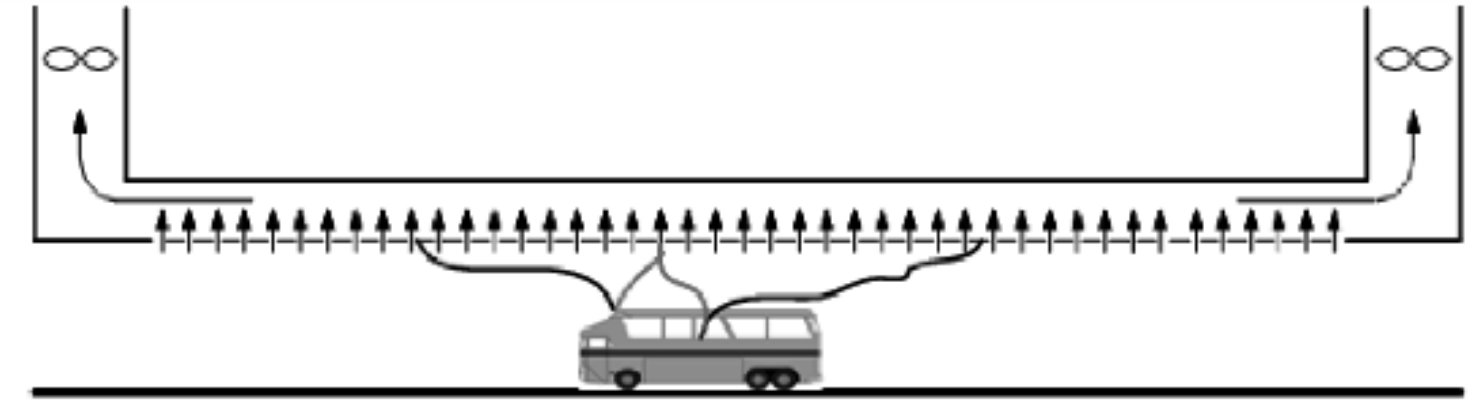
Semi-Transverse (Exhaust)

Ventilation Systems
Transverse



Full-Transverse

Ventilation Systems
Transverse



Smoke Exhaust for Transverse Systems

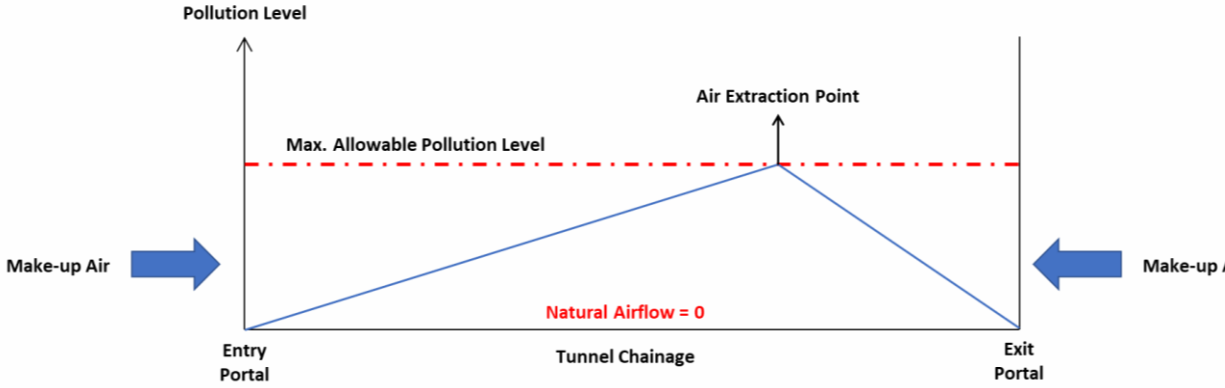
Ventilation Systems Transverse

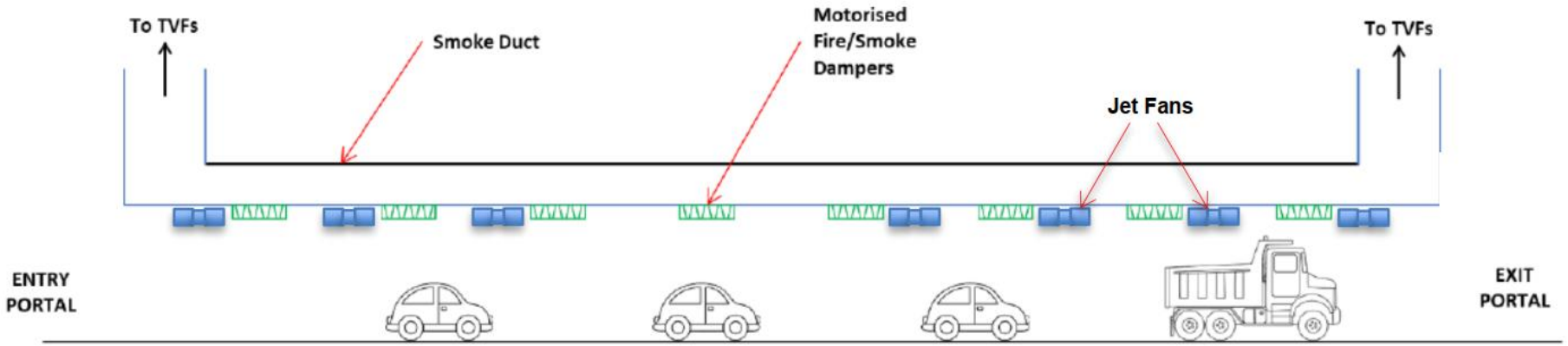
Pros and Cons

- Maximum ventilation rate is limited by duct size for full transverse system
- Able to handle fire incident for unidirectional and bidirectional traffic
- Maximum airflow rate is limited by tunnel cross sectional area for semi-transverse systems (usually <11m/s). May not suitable for very long tunnels.
- Cannot handle large fire due to limited exhaust rate per linear metre.
- High civil cost due to the space for ventilation duct(s).
- Not all the fresh air could be utilised especially for semi-transverse exhaust system.
- Not energy efficient due to higher pressure losses in the supply and/or exhaust ducts.
- Ventilation buildings would be required outside the tunnel which will increase construction costs.

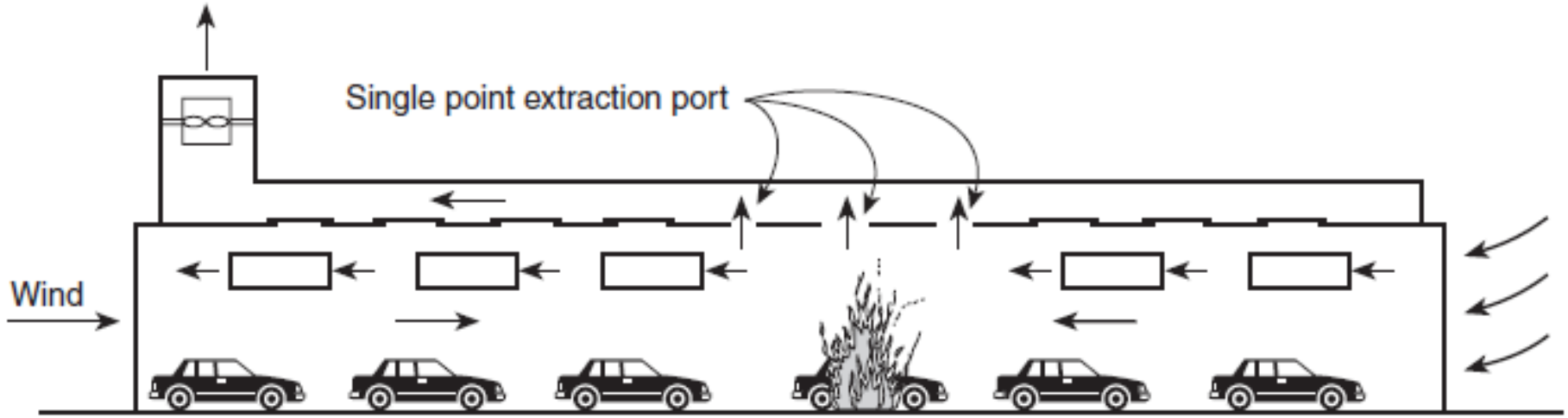
Ventilation Systems
Single Point Extraction

The system breaks the tunnel into two (2) longitudinal ventilation zones





Ventilation Systems
Single Point Extraction



Smoke Exhaust Mode

Ventilation Systems Transverse

Pros and Cons

- Able to handle high fire Heat Release Rate (HRR).
- Very efficient for normal ventilation as all the fresh air will be used for pollution dilution.
- High energy efficiency as the natural wind can help to ventilate the tunnel.
- Suitable for uni-directional and bi-directional traffic.
- Fire damage can be contained in short section of tunnel.
- Maximum airflow rate is limited by tunnel cross sectional area (usually <11m/s). May not suitable for very long tunnels.
- Construction costs would be higher due to the ventilation duct and the ventilation buildings.

Ventilation Systems
System Selection Considerations

Normal Ventilation Rate

- Vehicle emission data based on PIARC design guidelines
- Fleet composition (% of car, bus, lorry and truck)
- Ages distribution of the fleet
- Altitude of the tunnel
- Number of lanes with maximum throughput at different traffic speed

Considerations

- If the ventilation rate is higher than the tunnel cross area x 11m/s, multiple ventilation zones will be required for longitudinal and semi-transverse systems

Ventilation Systems
System Selection Considerations

Tunnel Operation

- Unidirectional traffic
- Unidirectional traffic for normal and bidirectional traffic for services or partial tunnel shut down
- Bidirectional traffic

Considerations

- For unidirectional traffic only tunnels, all the ventilation concepts can be considered. However, many countries imposed longitudinal ventilation zone length (shorter zone length for urban and longer zone length for rural.

Ventilation Systems
System Selection Considerations

Nature Wind

- Natural in-tunnel air velocity generates by concurrent atmospheric pressure between the entry and exit portals.

Considerations

- Transverse systems are not suitable as strong wind will carry the smoke away from the fire site.
- For longitudinal ventilation systems, the jet fan system shall have the thrust to overcome the adverse wind and maintain critical velocity at the upstream of the fire.
- For single point extraction system, the jet fan system shall have the thrust to stop the natural wind in the tunnel.

Tunnel Ventilation

Questions

Tunnel Ventilation

Thank You