Ventilation and Air Quality Monitoring

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Why Measure?

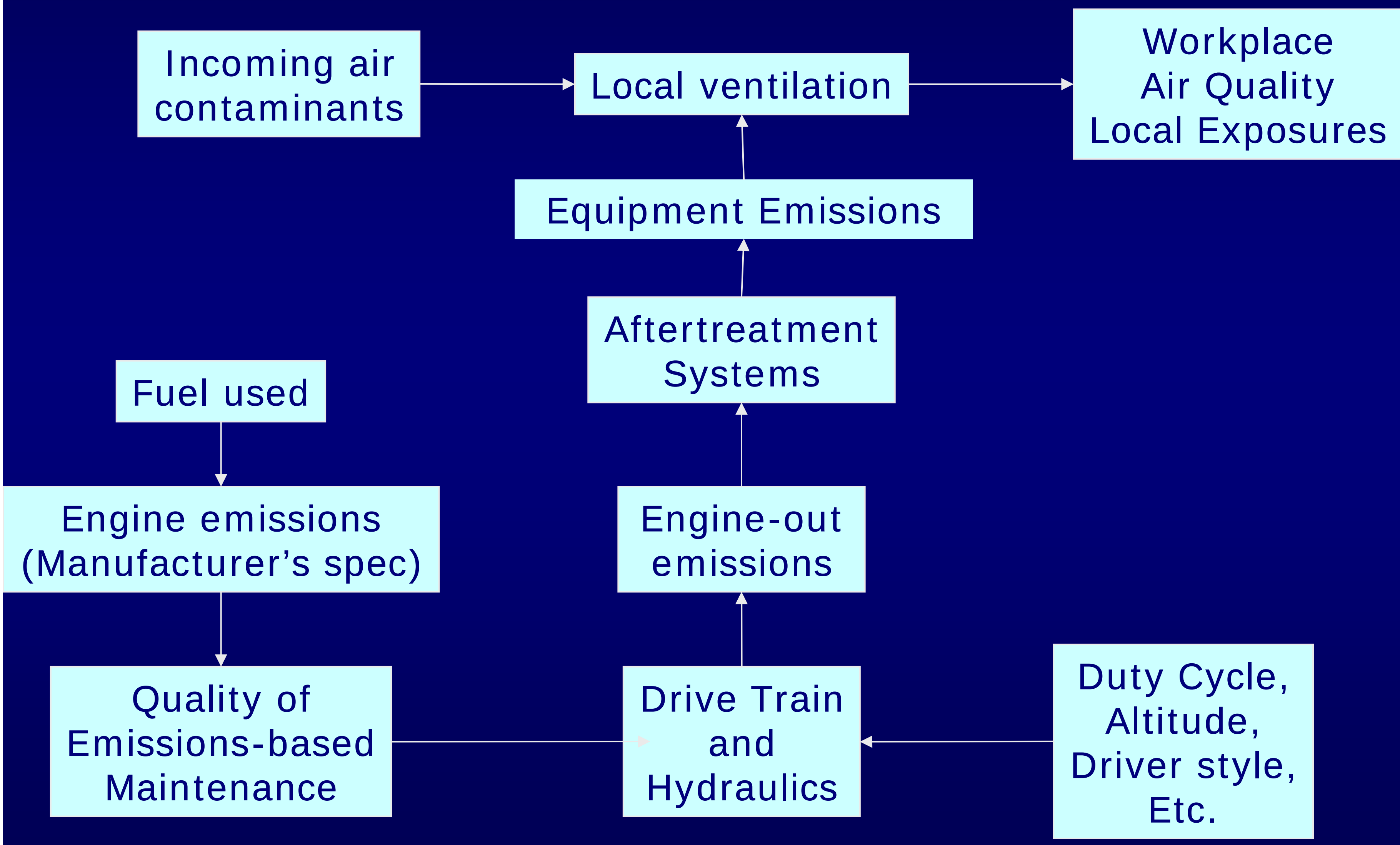
- Are the ventilation efforts effective?
- Define areas where ventilation needs improvement or emissions burden needs to be reduced.
- Assess effectiveness of emission controls.
- Determine whether controls introduce adverse contaminants (e.g., increase in NO_2 from catalyzed passive filters).
- Attribute cause when contaminant levels are excessive.
- Provide key knowledge needed to develop administrative controls which affect personal exposures.
- More…

In sum – provide the quality assurance and diagnostic information on the efforts to control diesel exhaust contaminants.

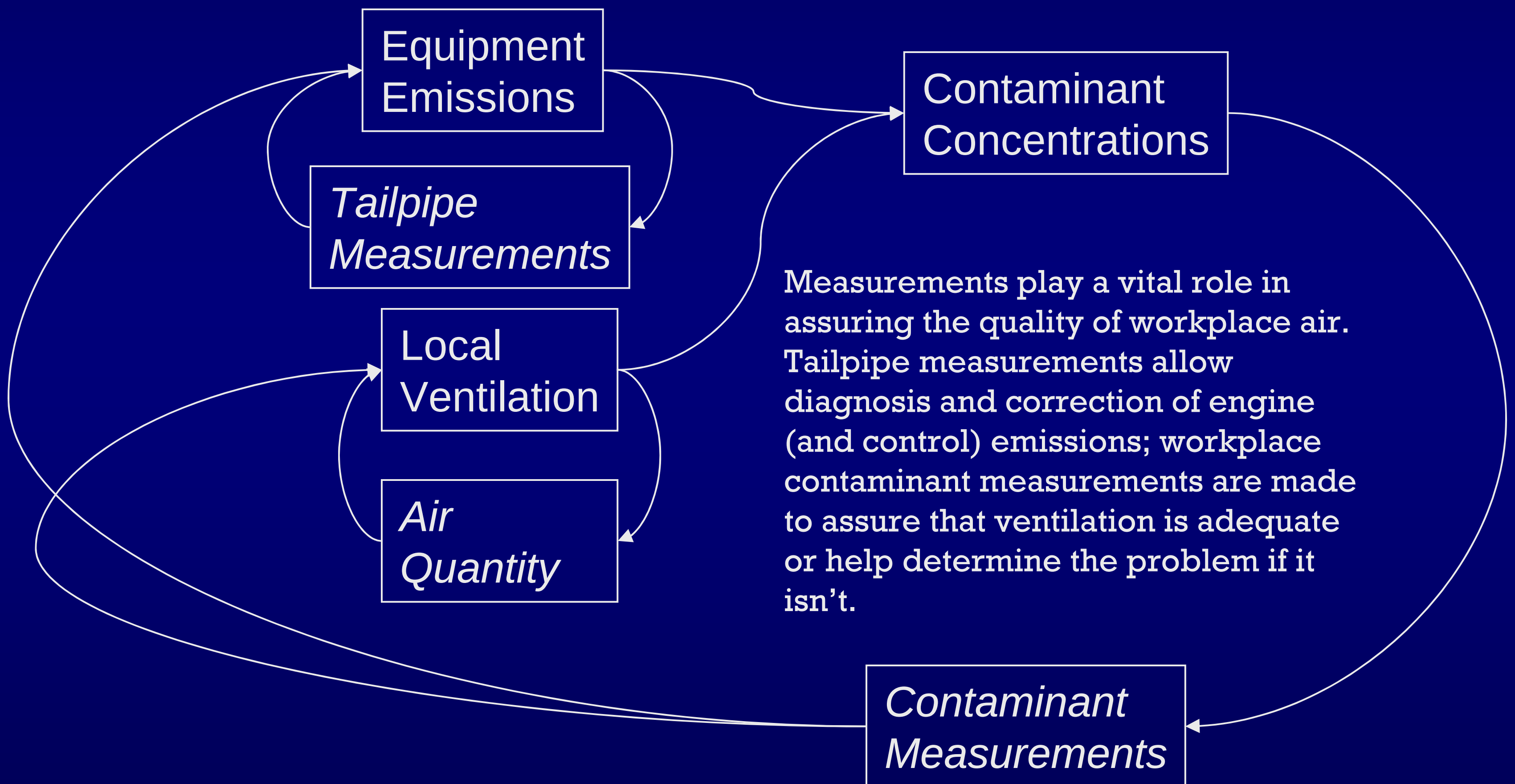
"Air Quality" Factory

- The introduction of a diesel powered equipment created an "air contaminant" production process within the underground mine.
- This production process can be modeled and subjected to applicable quality control procedures including the final product.
- Each contributing "ingredient" to the final product must be controlled for quality to the extent required to ensure that no "out of spec" ingredient gets into the final product:
  - Engine emissions (selection, in-use condition, controls)
  - Ventilation especially in areas of vehicle activity
  - Deployment (number of vehicles in a work area, etc.)
  - Etc.

Factors Affecting Workplace Air Quality

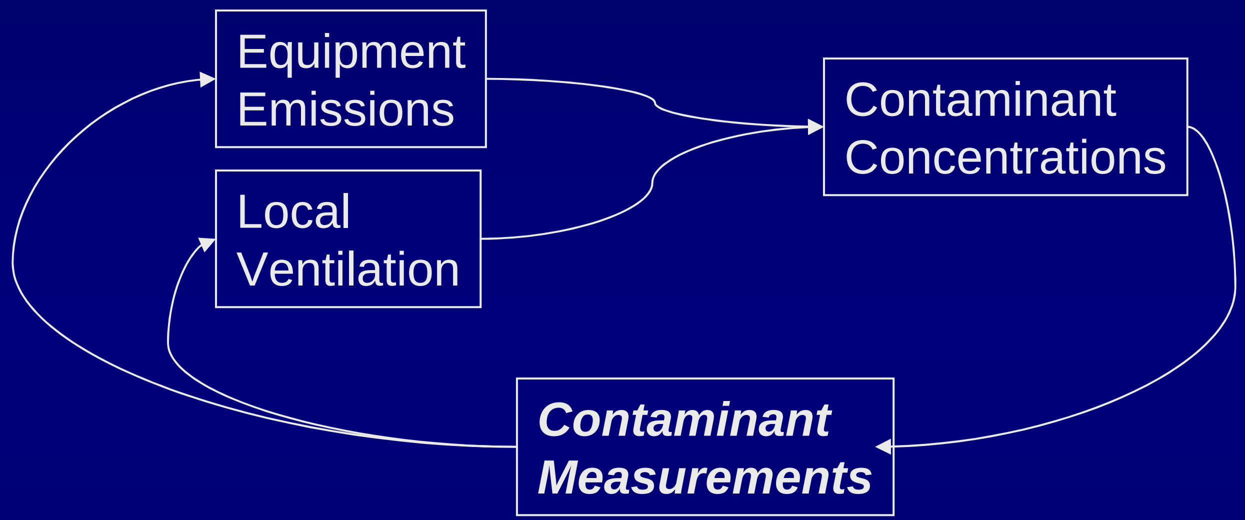


Air Quality / Exposure Control Loop



Measurements play a vital role in assuring the quality of workplace air. Tailpipe measurements allow diagnosis and correction of engine (and control) emissions; workplace contaminant measurements are made to assure that ventilation is adequate or help determine the problem if it isn't.

How workplace contaminant measurements can be used



Air contaminant measurements are able to determine whether an excessive contaminant concentration is caused by out of spec equipment or inadequate ventilation

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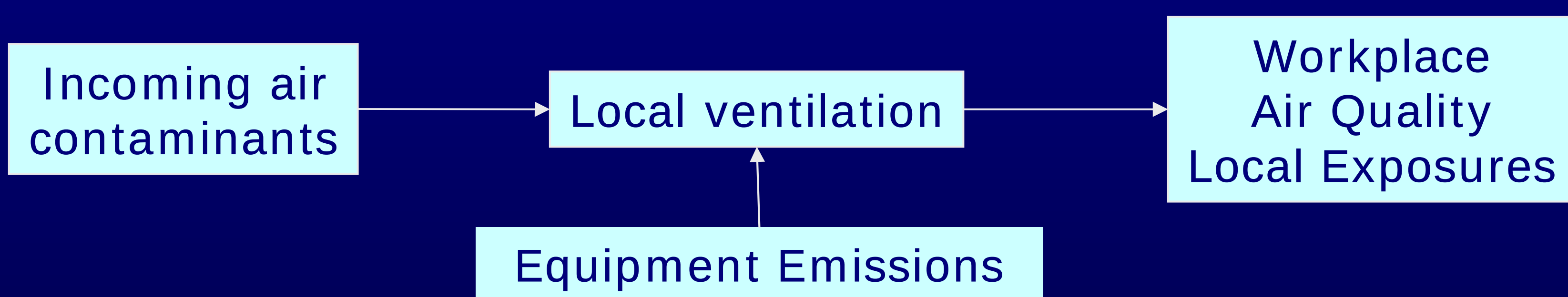
Air contaminant limits

- MSHA regulations set limits on diesel exhaust contaminants for an 8-hr shift or equivalent
  - Gases – ACGIH 1973
    - Carbon monoxide, CO, 50 ppm
    - Nitrogen oxide, NO, 25 ppm
    - Nitrogen dioxide, NO_2, 5 or 3 ppm (ceiling, not to be exceeded)
    - Carbon dioxide, ½% (5000 ppm)
  - DPM (using a surrogate)
    - 350 $\mu g/m^3$ TC
    - Final 160 $\mu g/m^3$ TC (or ??? EC)

Air Quality Monitoring Strategy

- Contaminant concentrations in the local workplace air are the result of three components:
  - Contaminant concentrations of the air source
  - Tailpipe emissions of the equipment in the area
  - The local air quantity and distribution



Air Quality Monitoring Strategy

Objective: to determine concentrations of contaminants in a localized workplace and determine how well the ventilation is handling the vehicle emissions in that area

Observations and Facts

- Observation: It is not possible to ensure that air quantities remain the same day to day and this needs to be accounted for when measurements of the same area are compared over time or after controls change.
- Fact: Dilution by ventilation affects EVERY exhaust contaminant EQUALLY.
- Fact: The amount of carbon dioxide CO_2 in tailpipe exhaust is directly related to the amount of fuel burned, energy expended, etc. by the equipment irrespective of any control technology including fuels
- Fact: Control technology and engine condition affect the relative proportion of contaminants to exhaust CO_2.
- Observation: Controls all strive to reduce unwanted contaminants from engine exhaust (in relation to CO_2).

An Example, a Puzzle

Local workplace concentration of EC (TC) in the same area is measured every couple of weeks. Sometimes it is okay, sometimes it is unacceptable. Corrective action needs to be taken. What should it be?

- Increase ventilation?
- Reduce number of vehicles?
- Is one vehicle smoking excessively?
- Target one or more vehicles for filters?

Eliminate influence of intake contamination

- Because the air being supplied to the workplace under surveillance may be contaminated by upstream activities, any measurement of local concentrations must include *simultaneous* measure of the same contaminant in the air being used to ventilate that workplace.
- The NET contribution to the workplace contaminant by the local vehicles is what is needed, and this is obtained by subtracting the contaminant concentration of the intake air from that of the workplace being ventilated by that air.

Rule #1: Account for contamination of the incoming air by measuring the contaminant concentration simultaneously with the workplace being ventilated by that air.

The Puzzle Remains

- Let us assume for the example, that the results behave roughly the same (some are more okay, others are better but remain unacceptable) after subtracting out the EC (TC) concentration in the intake air. Corrective action needs to be taken. What should it be?
  - Increase ventilation?
  - Reduce number of vehicles?
  - Is one vehicle smoking excessively?
  - Target one or more vehicles for filters?

By obtaining measuring one additional contaminant, one is able to able to solve this puzzle. One uses the facts and observations mentioned earlier.

Benefits of measuring CO_2

- If on the days when the net EC (TC) is higher, the CO_2 is also higher, then inadequate ventilation is likely to be the problem on those days.
  - Additional equipment was being used and the ventilation couldn't cope;
  - Ventilation was misdirected, or otherwise didn't ventilate as it was intended;
- However, on the days when the net EC (TC) is "high" but the CO_2 is not noticeably different from the days when EC (TC) is okay, then the cause of elevated EC (TC) is a smoking engine being used on that day.

Rule #2: Use simultaneous CO_2 measurements to determine whether ventilation or engine emissions are the source of unacceptable concentrations of other gases and EC (TC).

Equipment Needed

- Instrumentation (at least two of each)
  - Hand held infrared CO_2 meter with data logging (Vaisala CARBOCAP® (GM-70)
  - Hand held electrochemical O_2, CO, NO, and NO_2 meter with data logging (Industrial Scientific, iTX..)
  - Diesel sampler (SKC) and pump, and/or
  - Real time logging diesel aerosol meter, (Haz-Dust® IV with diesel software) or NIOSH prototype ?
  - PC or laptop for data download

Procedure – Quick Survey

- Use CO_2 meter to discover any areas where ventilation may be of concern, i.e., not enough dilution air for the number of vehicles in the area including those upstream.
  - Mount on vehicle out of the way of the exhaust and operator's breathing zone
  - Log the full shift and look at the data for times when CO_2 was high; determine where the vehicle was at those times
  - Perform walk around surveys of workplaces, note concentrations and flag those that may be cause of concern. Experience will be the best teacher. Areas with over 5000 ppm (4600 net*) are definitely not being ventilated adequately.

*Note: Normal fresh air contains about 400 ppm CO_2 and this must be subtracted from all CO_2 readings used for "engineering" analysis.

Contaminant monitoring

- For "quick" survey, mount logging instruments with the CO_2 instrument on the vehicle
- Examine data for hot spots and unacceptably high levels;
- Instances when NO_2 is over the ceiling limit should be of concern.
- Engineering measurements (area samples)
  - When tracking or assessing contaminants other than CO_2, divide each by the corresponding *net* CO_2 concentration obtained *simultaneously* and in the *same* location, to get a contaminant ratio
  - Subtract upstream contaminant ratios from those obtained *simultaneously* in the area(s) of concern.
  - Experience and comparison to earlier data will allow detection of unusual conditions. For example if the NO_2 to CO_2 ratio jumps after installing a new passive filter on a vehicle being used in the area, the filter catalyst may be causing an NO_2 problem. The application of a filter (or biodiesel fuel) would cause a significant decrease in EC (TC) to CO_2 ratio.

Interesting Conclusion

- IF controls are in place (if needed), AND engine emissions are scrupulously kept in spec at all times, then CO_2 is the only measurement needed to be made to assure acceptable air quality. An upper limit on CO_2 can be set that assures that all contaminants are at acceptable levels, since the emitted contaminants (CO, NO, NO_2, and DPM) are being controlled at the source.

Engine Emissions, Limits, Dilution, & Air Quantity for Engine Tailpipe Exhaust Flow of 500 cfm

Gases	Name	Emission TCS	ACGIH Limit	Dilution Required	Air Quantity for 500 cfm
CO_2	Carbon Dioxide	8%	0.5%	16	8000 cfm
CO	Carbon Monoxide	0-200 ppm	50 ppm	0-4	0-2000
NO	Nitric Oxide	500 ppm	25 ppm	20	**10,000**
NO_2	Nitrogen Dioxide	30 ppm	3 / 5 ppm	10 / 6	5000/3000
NO_2	(Elevated)	120 - ?	3 / 5 ppm	40 / 24	20,000/12,000

Particles	Basis	MSHA PI	MSHA limit (metal)	Dilution	Air Quantity
DPM	1000 µg/m^3	10,000 cfm	(500 µg/m^3)	2	20,000 cfm
TC	(800 µg/m^3)	(10,000)	400	2	20,000
EC	(616 µg/m^3)	(10,000)	308	2	20,000
			MSHA limit (coal)	Filter	
DPM	1000 µg/m^3	10,000 cfm	**17 g/hr**	**88%**	N/A

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Table Observations

- Only 8000 cfm is needed to dilute CO_2 to the TLV of 5000 ppm when engine is operating at full power.
- However 10,000 cfm is needed to dilute NO to its TLV.
- With DOCs in use, CO is not a concern.
- In this example, to get to about 300 µg/m^3 EC, a dilution of 20,000 cfm or more is needed.

Not on the table but can be noted

- When exhaust DPM as EC is reduced by a control to 80% of its value (the PI is 2000 cfm), then the dilution air required is only 4,000 cfm.