Understanding Ambient Air Quality Instrument Operating Ranges

In order to maximize the performance of an air quality monitoring station, careful selection of instrumentations is essential. One of the key issues is to have a good understanding of what pollutants need to be measured and at what concentrations. There are several different types of air quality monitoring, these include:

Trace/Background Monitoring

This is performed in areas where there is no immediate source of pollutants, such as motor vehicles or industry and is aimed at obtaining "background" measurements for that region.

These stations typically measure a wide range of pollutants including PM10, PM2.5, O3, CO, NOy, NO2, NO, SO2 and meteorological conditions.

Concentrations for CO are typically less than 100 ppb and often less than 1 ppb for all other gases. PM concentrations are also low, often less than 10 ug/m3 for PM10 and 5 ug/m3 for PM2.5.

This application calls for special trace monitoring analysers capable of measuring at these very low concentrations.

Compliance Monitoring

This is performed in urban locations but removed from any immediate source of pollutants and is aimed at providing a good understanding of typical pollutant concentrations in the broad area. A typical city of a population of around 5 million, may have anywhere between 10 to 30 of these monitoring stations depending on local topography and available funding.

These monitoring stations measure "criteria" pollutants, which are gases that include O3, CO, NO2, SO2 and particulates such as PM10 and in some countries PM2.5.

The goal for these stations is to ensure that "typical" pollution concentrations don't exceed that countries standards and thus do not impact on the health and wellbeing of the population.

For instance the USEPA has established the following standards.

	Primary Standard
	Level
Carbon Monoxide	9 ppm (8 hr)
	35 ppm (1 hr)
Nitrogen Dioxide	53 ppb (annual)
	100 ppb (1 hour avg)
Ozone	75 ppb (8 hour avg)
	120 ppb (1 hour avg)
Sulfur Dioxide	30 ppb (annual)
	75 ppb (1 hr avg)
PM10	50 ug/m3 (24 hr avg)
PM2.5	15 ug/m3 (annual)
	35 ug/m3 (24 hr avg)

Roadside Monitoring

This is a specialized application where monitoring stations are installed close to roads and are aimed at providing a very good indication of pollutant concentrations inhaled by drivers or pedestrians in that location.

These monitoring stations are typically designed to measure emissions from traffic that include CO, NO2, SO2 and particulates (PM10 and PM2.5).

Hong Kong, a country with a significant amount of traffic related pollution provides an excellent example of the anticipated concentrations that will be seen at these monitoring stations.

The maximum observed 1 hour concentrations in Hong Kong in 2008 from all monitoring stations including roadside stations were as follows:

Parameter	Maximum 1 hr concentration
O3	207 ppb
CO	4.6 ppm
NO2	184 ppb
SO2	345 ppb
PM10	79 ug/m3

It should also be noted that the USEPA have established a new one hour goal for NO2 of 100 ppb directly aimed at reducing road side pollution health threats for millions of Americans. " For the first time ever, we are working to prevent short-term exposures in high risk NO2 zones like urban communities and areas near roadways," said EPA Administrator Lisa P. Jackson.

Wide range vs small measurement range

The presumption that it is beneficial to have the widest possible measurement range for instruments, is not true as the following issues need to be considered.

Ambient Concentrations are typically less than 500 ppb (5 ppm for CO)

As illustrated above, both by USEPA Criteria pollutant limits and maximum 1 hour concentrations obtained in Hong Kong, ambient concentrations are nearly always less than 500ppb for O3, NO2 & SO2 and less than 5 ppm for CO. PM10 concentrations rarely exceed 200 ug/m3, except in exceptional circumstances such as forest fires.

With the vast majority of air quality monitoring stations we have installed and configured the most common operating range configured are:

O3	0-500 ppb
CO	0-5 ppm
NO2	0-500 ppb

SO2	0-500 ppb
PM10	0-1000 ug/m3

Autoranging of Instruments

While the above concentrations are very typical of all monitoring environments for compliance and roadside monitoring, modern microprocessor based analysers such as the Ecotech Serinus have the ability of autoranging and are able to capture concentrations approximately 20 to 40 times greater than this if necessary. Which is more than sufficient for all ambient/roadside monitoring applications.

USEPA approved measurement ranges

The USEPA approves criteria pollutant analysers over prescribed ranges, hence even if the analysers have a wide range they must still be operated on the range specified below to meet USEPA approval.

The USEPA approves analysers across the following ranges:

O3: 0-500 ppb

CO: 0-50 ppm

NO2: 0-500ppb

SO2: 0-500 ppb

Calibration of analysers

It is recommended by all manufacturers that analysers should be calibrated at multiple concentrations (typically 0, 20, 40, 60, 80%) of the measurement range every three months. It is also highly recommended that an overnight calibration check performed at 80% of the measurement range also be performed.

The aim of these calibrations is to perform them at the typical ambient concentrations measured in that location in order to achieve the great possible accuracy and precision for the measurement. If an overly high range such as 0-100 ppm (O3, NO2, SO2) is configured in the analyser then in order to operate the analyser at this range over night span calibration checks would need to be performed at 80 ppm (80% of range) in order for this range to be acceptable. This would result in extremely poor precision and

accuracy for concentrations measured below 1 ppm as the precision for instruments is typically between 0.5 to 1% of operating range.

Analyser Precision & Lower Detection Limit

If a measurement range for O3, SO2 and NO2 was configured to be 0-100 ppm and 0-1000 ppm for CO then with a typical precision of 0.5% of the measurement range, the best precision and lower detection limit would be approximately:

O3: 0.5 ppm

CO: 5 ppm

NO2: 0.5 ppm

SO2: 0.5 ppm

This is obviously far higher than concentrations observed in highly polluted roadside environments.

Analog Outputs

Although most modern analysers are microprocessor based and communication with a data acquisition system is through digital communication such as RS232, USB or Ethernet, if analog outputs are also desired to be used then configuring analog outputs for a range of 0-100 ppm would also create a significant error . If you consider a 0-5 VDC analog output for a measurement range of 0-100 ppm, then with a typical analog output accuracy of 20 mV (0.4%) then the concentration accuracy would be 0.4 ppm, which is approximately twice that of typical maximum observed concentrations even in roadside environments. Therefore analog outputs should be configured across the narrowest possible output range such as 0-500 ppb, resulting in an accuracy of +/-2 ppb.

Toxic Levels of Criteria Pollutants

It is also noteworthy to discuss toxic concentrations of criteria pollutants. Many international organizations have established both Maximum Personnel Exposure Limits (PEL) , Short Term Exposure Limits (STELs) and ceiling limits (concentrations should never exceed this limit) to many gases including O3, CO, NO2 and SO2. The levels listed below are not found in even heavily polluted ambient environments, they are only experienced in industrial application such as those immediately surrounding an ozone generator or immediately surrounding a furnace or in confined spaces where a combustion source is located.

Parameter	PEL	Other
NO2	0.1 ppm (NIOSH)	5 ppm (immediately dangerous to life) ACGIH 1 ppm (15 minute short term exposure limit)
O3	0.1 ppm (OSHA)	5 ppm (immediately dangerous to life) NIOSH 0.1 ppm (ceiling limit) NIOSH
SO2	5 ppm (OSHA)	5 ppm (short term exposure limit) NIOSH
CO	50 ppm (OSHA)	200 ppm (Ceiling value)NIOSH

OSHA - United States Department of Labour – Occupational Safety and Health Administation

NIOSH - National Institute for Occupational Safety and Health (NIOSH)

Conclusion

It is important when specifying instruments and instrument ranges for air quality monitoring that close attention be paid to typical expected maximum concentrations in order to choose analysers which have ranges suitable to measure these concentrations. While initially it would appear choosing instruments with the widest possible range would be ideal, doing this creates significant problems and should be avoided.