Audit of Ambient Air Monitoring Stations
for the Sistema de Monitoreo Atmosférico de la Ciudad de México

Submitted to:

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EXECUTIVE SUMMARY

Compañía Bettel Ecologica and EPA Systems, LLC were contracted by the Environmental Secretariat of the Government of the Federal District (*Secretaría del Medio Ambiente del Gobierno del Distrito Federal* (GDF)) to support the GDF in conducting Technical Systems and Performance (TS&P) audits of selected stations within the Mexico City ambient air monitoring network. Previously these audits were performed in 2003 and 2005 by the USEPA Office of Air Quality Planning and Standards (OAQPS) with follow-up audits conducted by GDF auditors. Prior to this, audits were performed as an adjunct to a research program in Mexico City by the USEPA Office of Research and Development (ORD).

This report details the results of the TS&P audits conducted between 14 and 18 December 2009 on 10 of the GDF ambient systems. The audits were performed using an independent Protocol 1 calibration standard and new Environics Model 6103 calibrator and Environics Model 7000 clean air source. The performance audit consisted of challenging each nitrogen oxides (NO_x), sulphur dioxide (SO_2), carbon monoxide (CO) and ozone (O_3) analyzer at four to five upscale data values plus zero. In addition, the nitrogen dioxide (NO_2) convertor efficiency for each NO_x analyzer was tested using a gas-phase titration approach using three different NO concentrations and three different ozone concentrations. Finally, for those stations equipped with continuous PM analyzers the flow rate through the analyzer was checked using a calibrated BGI deltaCal® calibrator to ensure that the flow rate though the analyzer was sufficient to maintain the cut-point of the sampling head.

The systems audit showed that GDF has an effective system for station operation and calibration. Each operator carries a PDA to record site information that is downloaded and archived each day. The diagnostic information from each instrument is collected during each site visit. There are control charts kept in each site that records the historical zero and span data from each instrument calibration. In addition, there is a master list of maintenance and calibration activities posted in each shelter so that the operators know what activities need to be performed during each site visit. A review of the site log books showed the logs were signed and dated and that all activities during each site visit were recorded. The only room for improvement is some inconsistency with the notation of arrival and departure times. The sites were all very clean and well kept and the site instrumentation was neatly plumbed and wired making maintenance and servicing of the instrumentation much easier. The operators that the auditor had the opportunity to meet and interact with demonstrated a strong commitment to performing quality work and expressed a lot of pride with the jobs they did.

Overall, the performance audit demonstrated that the sites were well run and collecting valid and defensible data. Of the 40 instruments audited, none of the CO or NO_x analyzers had

responses that were outside of the audit objective of ±15%. One ozone analyzer (EAC Site) may have had a low response, slightly outside of the audit objective, but this may have been an artifact of the auditor having to learn how to operate a new calibrator that he wasn't familiar with, including some of the nuances of that instrument. While this instrument's performance should be reviewed by GDF staff to make sure it is indeed operating properly, the auditor believes the low ozone response may well have been human error.

The only potential for system improvement for the ten sites audited would be regarding the SO_2 monitoring. Three of the 10 sites had SO_2 instruments that were either outside of the average or individual audit objective of ± 15%, and/or had such a slow response that there was a strong potential that any transitory ambient SO_2 spikes would be missed by the instruments. Understanding that the SO_2 analyzers are the slowest to respond of the criteria instruments, these analyzers should reach 95% of an input value within five minutes. Response times greater than this can result in the instrument missing transitory peaks. Figures ES-1 to ES-4 show the average audit responses at the ten sites for each of the four criteria pollutant analyzers.

The continuous PM analyzers (both PM_{10} and $PM_{2.5}$) were evaluated to determine if the flow rates through the system were adequate to ensure that a proper cut-point was achieved through the sample inlets. The total flow rate should be 16.67 lpm ± 10%. All of the PM analyzers were well within this limit.

Based on the 10 sites audited, the audit demonstrated that the GDF monitoring network has a good QA/QC systems in place to operate the network and that performance-wise, the instrumentation is, with small exception, operating within acceptable limits. There was an indication of a potential need to improve the sulphur dioxide monitoring system based on the slow response times and substandard performance at three of the ten sites.

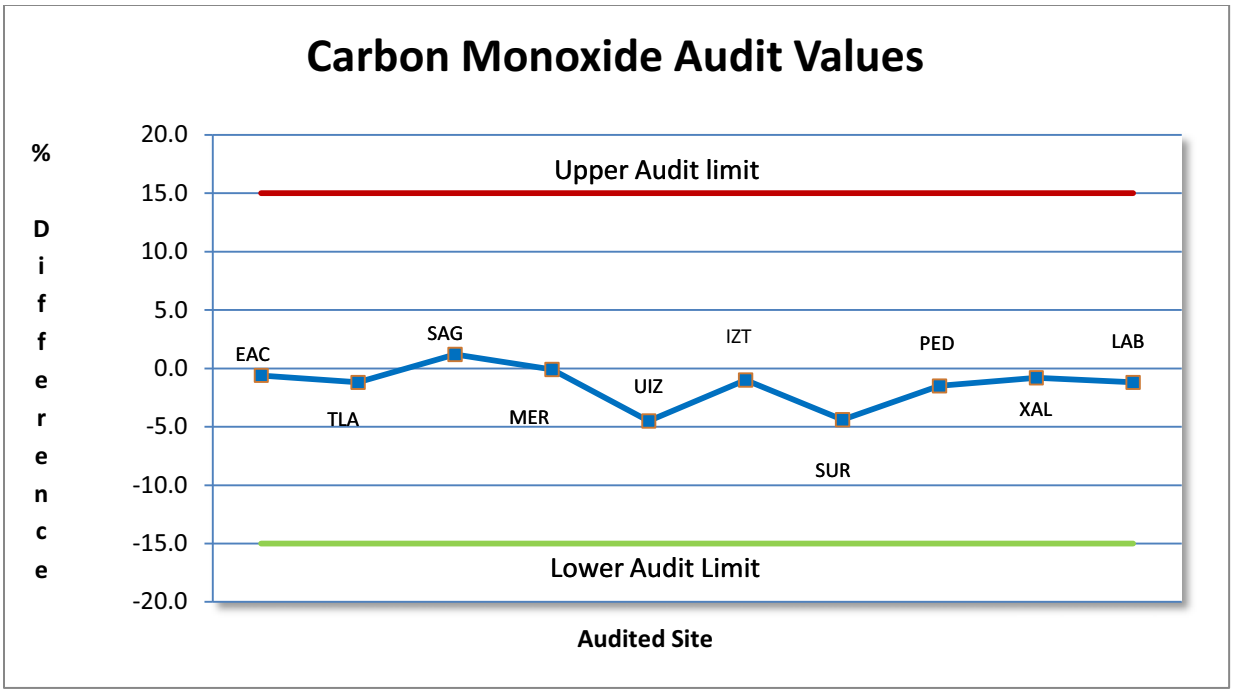

Figure ES-1. Summary of Average Carbon Monoxide Audit Results

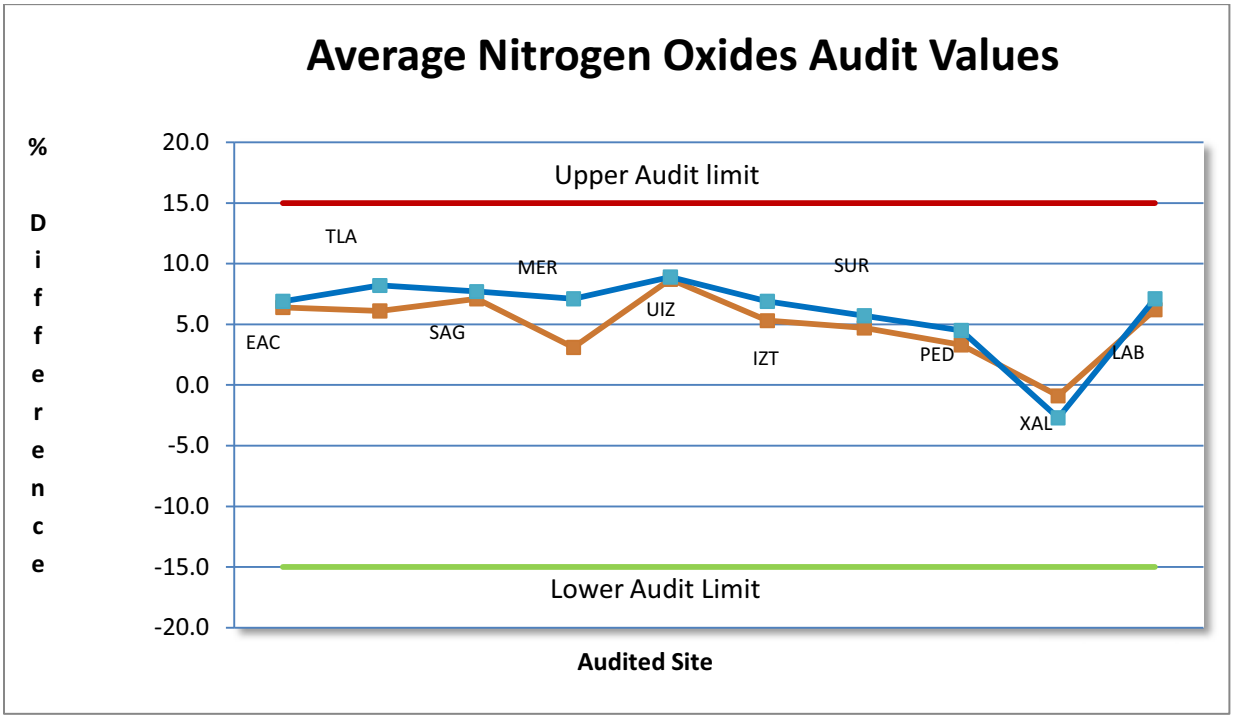

Figure ES-2. Summary of Average Nitrogen Oxides Audit Results

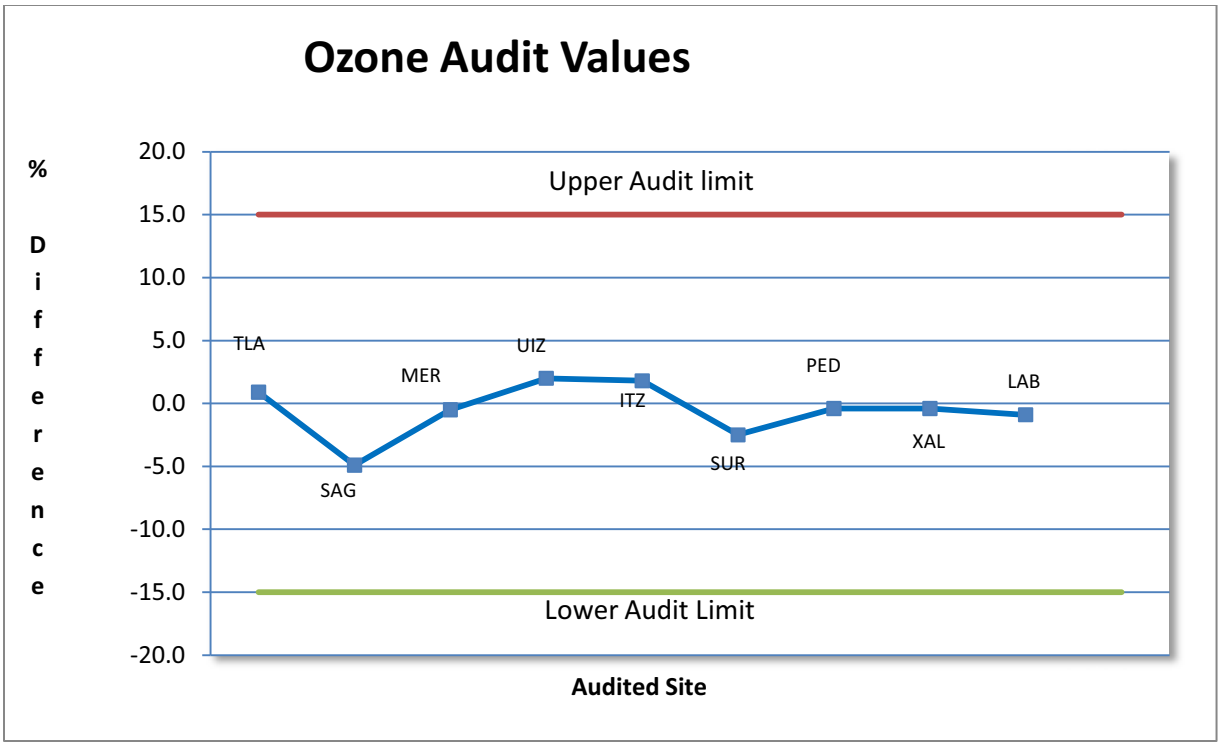

Figure ES-3. Summary of Average Ozone Audit Results

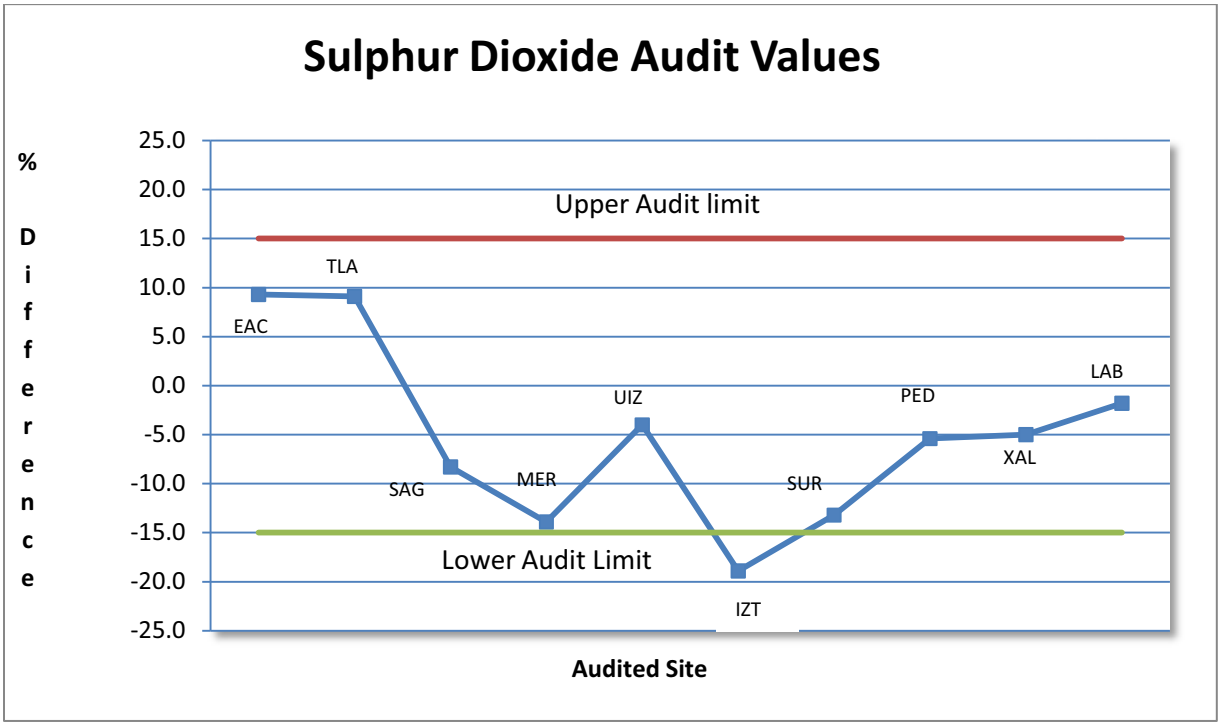

Figure ES-4. Summary of Average Sulphur Dioxide Audit Results

1.0 INTRODUCTION

This report details the technical systems and performance (TS&P) audit conducted on ten (10) ambient air monitoring sites operated by Ciudad de Mexico. Mexico City Atmospheric Monitoring System (Sistema de Monitoreo Atmosférico de la Ciudad de México, SIMAT) operates a total of 34 stations in and around Mexico City. The audit was conducted between 1 and 6 December 2009 and was designed to determine the operational state of the individual criteria monitors (performance audit) as well as evaluate the systems and procedures used to calibrate and operate the network. The network also has particulate monitoring (manual and continuous) and meteorological monitoring, but these parameters were not part of the audit.

1.1 Mexico City Metropolitan Area

The Mexico City Metropolitan Area (MCMA) lies in an elevated basin at an altitude of 2,240 meter above mean sea level (amsl), near the center of the country (19º25' N latitude, 99º10' W longitude). The floor of the basin is confined on three sides by mountain ridges with a broad opening to the north and narrowed gap to the south-southwest. The surrounding peaks attain an elevation of nearly 4,000 meter asml. The metropolitan area is located on the southwest side of the basin and covers about 1500 km^2. The MCMA includes the 16 "delegaciones" within the Federal District and clusters of municipalities (municipios) including 37 in the State of Mexico. The Federal District (DF) is the country capital and is home to the national political institutions, the greatest concentration of economic investments and most of the country's industrial and financial infrastructure. MCMA has over 18 million inhabitants.

1.2 Secretaría del Medio Ambiente del Gobierno del Distrito Federal

The Secretariat of the Environment of the Federal District Government (Secretaría del Medio Ambiente del Gobierno del Distrito Federal) is responsible for environmental policies and programs, including implementing local and federal laws, in the Federal District. Since 1993, the Secretariat of the Environment of the Federal District Government has been the primary organization responsible for ambient air monitoring in the Mexico City Metropolitan Area and operates the Mexico City Atmospheric Monitoring System (Sistema de Monitoreo Atmosférico, SIMAT) for this purpose.

The Atmospheric Monitoring System consists of 54 monitoring stations, a support laboratory, an environmental information center, and an information technology support center. Monitoring is further segregated into an Automatic Ambient Air Monitoring Network (Red Automática de Monitoreo Atmosférico, RAMA), a Manual Particulate Monitoring Network, an Atmospheric Deposition Network, and a Meteorological Network. With the support of the environmental information center and the information technology support center, monitoring data are translated daily and hourly into the Metropolitan Area Air Quality Index (Índice Metropolitano de la

Calidad del Aire, IMECA). The IMECA is widely distributed to public and private sector organizations in the Mexico City area to assist in making public health decisions.

Currently the SIMAT network consist of 34 automated stations (O_3, NO_X, SO_2, CO, PM_{10} and $PM_{2.5}$), 15 manual stations (TSP, PM_{10}, $PM_{2.5}$ and heavy metals), 15 meteorological stations (RH, T, WDR, WSP, P and UV radiation) and 16 atmospheric deposition stations (wet and dry atmospheric deposition).

The audit was performed at 10 of the 34 automatic station sites operated as part of the SIMAT network. A summary of the audit schedule along with the parameters audited is summarized in Table 1 below. A map showing the location of the 10 sites is presented in Figure 1-1. Site descriptions for the 10 sites are presented below.

Table 1.1 - Summary of Site Parameters

Site Name	Initals	Date Audited	Parameters Monitored
ENEP Acatlán	EAC	1/12/09	NO_x, CO, O_3, SO_2, PM_{10}
Tlalnepantla	TLA	1/12/09	NO_x, CO, O_3, SO_2, PM_{10}, $PM_{2.5}$
Merced	MER	2/12/09	NO_x, CO, O_3, SO_2, PM_{10}, $PM_{2.5}$
San Agustin	SAG	2/12/09	NO_x, CO, O_3, SO_2, PM_{10}, $PM_{2.5}$
UAM Iztapalapa	UIZ	3/12/09	NO_x, CO, O_3, SO_2, $PM_{2.5}$
Iztacalco	IZT	3/12/09	NO_x, CO, O_3, SO_2, PM_{10}
Santa Úrsula	SUR	4/12/09	NO_x, CO, O_3, SO_2, PM_{10}
Pedregal	PED	4/12/09	NO_x, CO, O_3, SO_2, PM_{10}
Xalostoc	XAL	5/12/09	NO_x, CO, O_3, SO_2, PM_{10}
Ciudad de Mexico Laboratory	LAA	5/12/09	NO_x, CO, O_3, SO_2

Note, for continuous PM_{10} or $PM_{2.5}$ only flow rates were audited

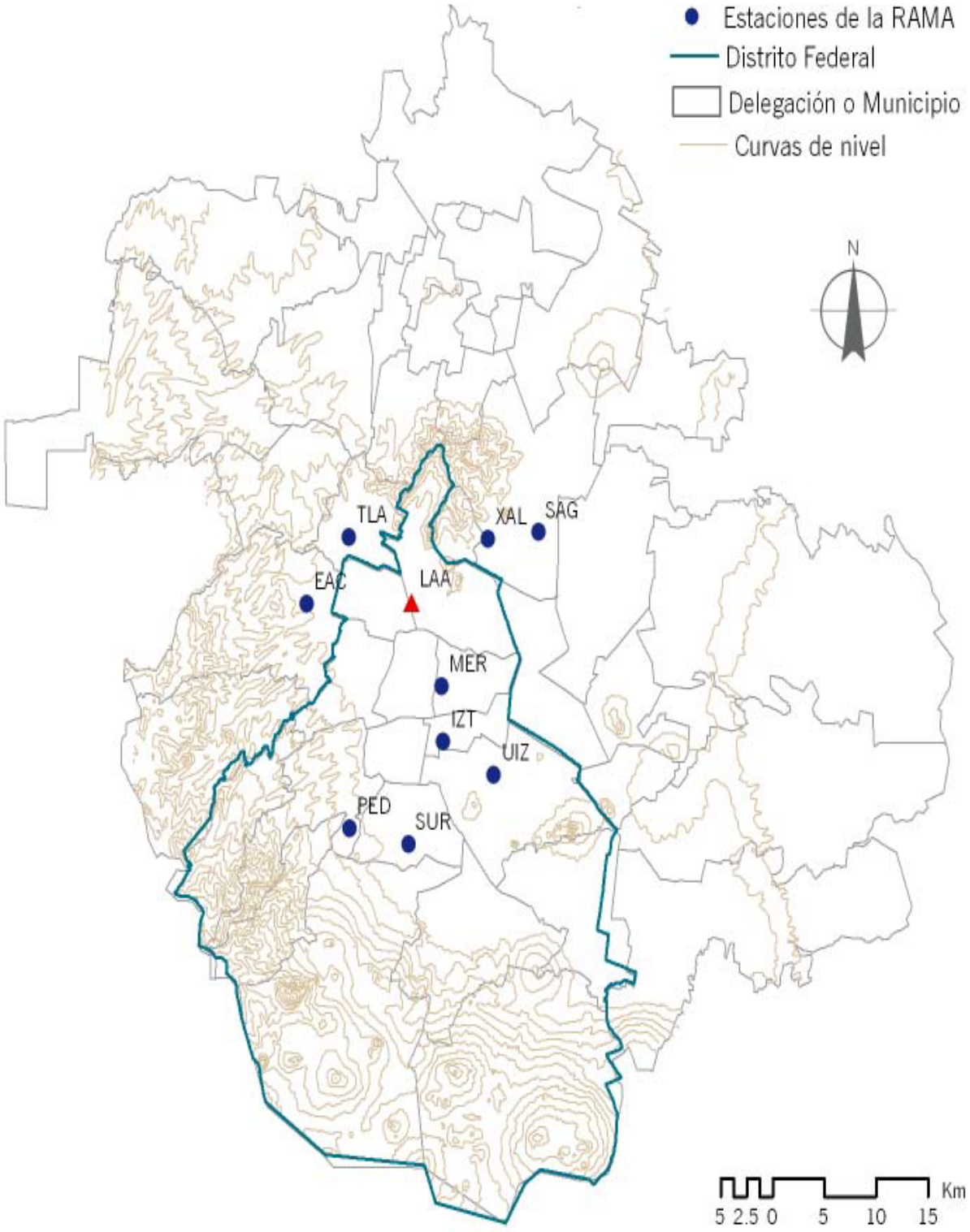

Figure 1-1. Map of Audited Mexico City Network Sites

1.3 Site Information

Site: ENEP Acatlán EAC

Address:

Avenida Alcanfores s/n esquina con San Juan Totoltepec, Colonia Santa Cruz Acatlán, Municipio de Naucalpan, Estado de México, CP 53240.

19º28'54.9'' N latitude, 99º14'35.8'' W longitude.

Description:

This station is located at the campus of the National School of Professional Studies in an Ekto Shelter on the top of the second floor of the Odontology Clinic building. There is a major avenue near the station with moderate traffic. There is a small parking lot near the clinic. Sample Inlet is 12 m above ground level.

Site: Tlalnepantla (TLA)

Address:

Glorieta de Atlacumulco. Avenida Toluca s/n, Glorieta Atlacomulco, Colonia Tlalmex, Municipio de Tlalnepantla, Estado de México, CP 54070.

19º31'42.2'' N latitude, 99º12'15.2'' W longitude.

Description:

This station is located in a shed on the top of a 2 meter platform in the northwest of the city in the municipality of Tlalnepantla, Estado de México. This is a residential neighborhood. There are no major streets adjacent to this site. This site is downwind from a major industrial area located north of the site. Sample Inlet is 6.8 m above ground level.

Site: Merced (MER)

Address:

Avenida Congreso de la Unión No. 148, Colonia Merced Balbuena, Delegación Venustiano Carranza, México D. F., CP 15860.

19º31'27.8'' N latitude, 99º07'09.4'' W longitude.

Description:

This station is near the downtown of Mexico City in a shed on the top of a health center. The streets around the station are wide and heavily traveled. There is a three story

secondary school to the south that blocks the wind from that direction. In addition, there is an elevated Metro railway to the west. Sample Inlet is 4.5 m above ground level.

Site: San Agustín (SAG)

Address:

Calle “Sur 88” esquina con Calle "Sur 90", Col Nuevo Paseo de San Agustín, Municipio Ecatepec de Morelos, Edo de Méx. CP 55130.

19º31’56.1’’ N latitude, 99º01’47.8’’ W longitude.

Description:

This station is in a residential area in the northeast section of Mexico City in the municipality of Ecatepec de Morelos in the Estado de México. The station is in an Ekto shelter on the roof of a health center. There are no major streets adjacent to this site. Sample inlet is 6.2 m above ground level.

Site: UAM Iztapala (UIZ)

Address:

Universidad Autónoma Metropolitana, Campus Iztapalapa. Av. San Rafael Atlixco No. 186, Colonia La Vicentina, Delegación Iztapalapa, D.F. CP 09340.

19º21’39.2’’ N latitude, 99º04’26.0’’ W longitude.

Description:

This station is located on the top of the third floor building at Universidad Autónoma Metropolitana Campus and housed in an Ekto Shelter. There are no major streets adjacent to the station as the station. Sample inlet is 20 m above ground level.

Site: Iztacalco (IZT)

Address:

Calle Guillermo Prieto No. 73 esquina con Melchor Ocampo súper manzana 4, Manzana 17 Lote 8, Col. Campamento 2 de octubre, Delegación Iztacalco, Distrito Federal, C.P. 08930.

19º23’03.9’’ N latitude, 99º07’03.5’’ W longitude.

Description:

This station is located in a low-income residential area and contained in a Shelter One shelter on the top of the second floor of a health center. There are wide streets around the station but they are not heavily traveled. Sample inlet is 11 m above ground level.

Site: Santa Ursula (SUR)

Address:

Centro de Salud "Dr. Gustavo A. Rovirosa Pérez". Calle San Gabriel No. 517, Colonia Pedregal de Santa Úrsula, Delegación Coyoacán, México D.F. CP. 04600.

19º18'49.2'' N latitude, 99º08'58.8'' W longitude.

Description:

This station is in a residential area at the south of Mexico City. The site is in a shed on the top of a health center. There are no major streets adjacent to the station. Sample inlet is 6 m above ground level.

Site: Pedregal (PED)

Address:

Escuela Primaria "John F. Kennedy". Calle Cañada No. 370 esquina con Avenida Cráter, Colonia Pedregal de San Ángel, Delegación Álvaro Obregón, México D.F. CP 01900.

19º19'29.0'' N latitude, 99º12'13.4'' W longitude.

Description:

This station is in a high-income residential area at the southwest of Mexico City, housed in a shed on the top of the second floor of an elementary school. There are no major streets adjacent to the station. Sample inlet is 11 m above ground level.

Site: Xalostoc (XAL)

Address:

Km 13.5 de la Antigua Carretera a Pachuca (Vía Morelos) y Calle del Hierro, Colonia Xalostoc, Municipio Ecatepec de Morelos, Estado de México, CP 55540.

19º31'39.9'' N latitude, 99º04'35.2'' W longitude.

Description:

This station is in an industrial/commercial/residential area. The site is in a shed on the back lot of a car dealership. The station is less than 10 meter away from a major avenue

with heavy traffic. The inlet location is somewhat blocked by an automobile detail building on one side of the shed. Sample inlet is 4.5 m above ground level.

1.4 Background

This section provides background on the organizations involved with this audit.

1.4.1 Secretaría del Medio Ambiente del Gobierno del Distrito Federal (GDF)

The Secretariat of the Environment of the Federal District Government (*Secretaría del Medio Ambiente del Gobierno del Distrito Federal*) is responsible for environmental policies and programs, including implementing local and federal laws, in the Mexico City metropolitan area (Federal District and adjoined municipalities in the State of Mexico). The GDF became the primary organization responsible for ambient air monitoring in the Mexico City area in 1993 when the Automatic Ambient Air Monitoring Network (RAMA) was transferred to the GDF.

Prior to the early 1970's, air quality monitoring in Mexico City was part of the Normalized Pan American Sampling Network (*Red Panamericana de Muestreo Normalizado*). In 1971, Mexico passed the Law for Preventing and Controlling Environmental Contamination, (*Ley para Prevenir y Controlar la Contaminación Ambiental*). In 1972 the Subsecretary for Environmental Improvement (Subsecretaría de Mejoramiento del Ambiente) was created under the Secretary of Health. These events led to the creation of a 48 station National monitoring network, with 22 of these stations being in the Mexico City air basin. Currently the Mexico City Atmospheric Monitoring System (SIMAT) consists of 54 monitoring stations, a support laboratory, an environmental information center, and an information technology support center. Monitoring is further segregated into an Automatic Monitoring Network (RAMA), a Manual Particulate Monitoring Network, an Atmospheric Deposition Network, and a Meteorological Network. With the support of the environmental information center and the information technology support center, monitoring data are translated daily and hourly into the Metropolitan Area Air Quality Index (*Índice Metropolitano de la Calidad del Aire* (IMECA). The IMECA is widely distributed to public and private sector organizations in the Mexico City area to assist in making public health decisions.

1.4.2 Secretariat of the Environment and Natural Resources (SEMARNAT)

The Secretariat of the Environment and Natural Resources (*Secretaría de Medio Ambiente y Recursos Naturales* (SEMARNAT)) is the primary federal agency responsible for environmental protection in the Country of Mexico. The Sub-secretary of Environmental Protection Management (*Subsecretaría de Gestión para la Protección Ambiental*) is the SEMARNAT organizational unit primarily responsible for environmental quality. However, the National Institute of Ecology (*Instituto Nacional de Ecología* (INE)) provides technical and research support for environmental issues (including monitoring).

Prior to this audit, the United States Environmental Protection Agency (USEPA) performed the Mexico City ambient air monitoring network audits as requested by the Environmental Secretariat of the Government of the Federal District (*Secretaría del Medio Ambiente del Gobierno del Distrito Federal* (GDF)) and the Pan American Health Organization (PAHO). The physical audits were performed by the USEPA Office of Air Quality Planning and Standards (OAQPS) and were conducted in 2003 and 2005. Prior to this, audits were performed as an adjunct to a research program in Mexico City by the USEPA Office of Research and Development (ORD). No additional audits by any agency of the USEPA since 2005 have been performed.

2.0 DESCRIPTION OF AUDIT METHODOLOGY

Performance audits are intended to independently evaluate the performance of an organization's monitoring equipment, calibration equipment, standards, and all operating, calibration, maintenance, quality assurance, and quality control procedures. Performance audits involve independent audit equipment, an independent auditor, and independent gas standards to challenge the instrumentation. On a routine basis, monitoring organizations perform audits using an internal, yet independent, auditor(s) and independent equipment. Gaseous pollutant audits were accomplished by challenging the instruments through the inlet to the sampling probe. The acceptance criterion for gaseous pollutants is 15% mean absolute difference and 15% for each concentration level of each pollutant analyzer. Monitors that exceed this criterion require corrective action. Also evaluated are the instruments response to individual audit concentrations, linearity, and blank evaluations.

Technical System Audits (TSAs) and Management System Reviews (MSRs) are reviews intended to evaluate how well the established quality system is working. TSAs are used to verify that appropriate technical and quality control procedures have been established and are being followed. For air monitoring organizations, some areas which are audited include:

- Written procedures;
- Documentation;
- Monitoring network design;
- Site appropriateness/siting requirements;
- Instrument operation;
- Laboratory procedures;
- Sample/data custody;
- Data handling systems;
- Data processing and calculation;
- Quality control; and
- Performance audit system.

Management System Reviews (MSRs) are evaluations of how effectively the QA program is working. These audits evaluate the overall quality system but may not effectively identify technical defects with the system. Possible elements of a MSR include the evaluation of:

- Organizational structure;
- Quality policy;
- Quality manager empowerment and effectiveness;
- Quality documentation;
- Corrective actions;
- Training and qualifications of staff;
- Commitment to quality by management and staff; and

- Overall effectiveness of the quality system.

The technical systems audit addressed a number of the issues outlined above.

2.1 Performance Audit Procedures

The station performance audits were performed using an Environics Model 6103 (S/N 4541) calibrator and Environics Model 7000 air source. These analyzers had never been used prior to this audit and were still in the box. An EPA Protocol 1 calibration standard manufactured by Aire Liquide of La Porte, Texas was used to make individual dilution concentrations for the NO_x, SO_2 and CO analyzers. Ozone concentrations were produced by the Environics calibrator using the on-board ozone generator and manufacturer certified photometer. Table 2-1 presents the concentrations of the individual analytes with a copy of the gas certification provided in Appendix A. The cylinder's certification is considered valid for 24 months from manufacture. The ozone concentrations were generated by the Environics 6103 (S/N based on the calibration done by the manufacturer on 24 July 2009. Normally, the ozone transfer standard should be calibrated every three months, but a grace period is provided for a "first-use" condition such as this analyzer.

During the audit, each instrument was challenged with at least five different gas concentrations (four to five upscale points plus zero). In addition, a gas-phase titration (GPT) was performed on each NO_x analyzer to test the NO_2 conversion efficiency. The GPT was performed by first creating a stable ozone concentration and then adding NO at a concentration approximately 50 ppb higher than the ozone concentration. This was done at three different ozone and NO concentrations to calculate the NO_2 converter efficiency. The flow rates though the continuous PM monitors were checked using a BGI DeltaCal calibrator (S/N 351). This device measures the total flow through the sample inlet which is critical to ensure that the cut-point of the sample head is accurate.

Because of site logistics, site security and shortage of open space, most of the air quality stations in the Mexico City network are located on the roofs of governmental buildings, such as clinics, schools, or universities. Each of the 10 sites was equipped with air quality monitors for nitrogen oxides (NO_x), sulphur dioxide (SO_2), ozone (O_3), and carbon monoxide (CO). Most of the sites also had continuous PM_{10}, $PM_{2.5}$, or both, however, only the main flow rates through the samplers were checked. In addition, many of the sites also had manual PM_{10} and $PM_{2.5}$ samplers along with meteorological sensors for wind speed and wind direction, ambient temperature, and solar radiation, but the audit scope did not include these parameters so they were not audited. In addition, elements of the TSA and MSR audits as described above were conducted evaluating the condition of each site, record keeping, and overall procedures that can impact the data quality. Due to the cost of air sources, calibrators, and individual gas standards, the sites are not

universally configured for automatic zero/spans and only two of stations were equipped with calibrators and air sources. During bi-weekly calibrations, an air source, calibrator and gas standard are taken to each site weekly.

The Mexico City staff conducts a series of calibrations at each site that include zero/spans, Level One precision checks, gas-phase titrations (GPTs) and multipoint calibrations. Table 2-2 summarizes the calibration frequency and calibration levels. The audit results from each station are discussed below in Section 3.

Table 2-1. Summary of Gas Standard Concentrations

Gas Standard	Cylinder Number	Concentration (ppm)	Date Manufacture	Stability (months)
SO_2	CC237122	29.9	23/10/2009	24
NO		27.1		
CO		3040		

Table 2-2. Summary of Calibration Type, Frequency, and Acceptance Criteria

Calibration Type	Recommended Frequency	Concentration Levels	Criteria
Zero	Weekly	Zero for CO, NO, SO_2, O_3	Zero ±3 ppb for O_3 Zero ±5 ppb for NO and SO_2 Zero ±0.5 ppm for CO
Level One Precision Check (performed though instrument's sample port) Note: This is referred to as zero and span calibrations by the network	Bi-Weekly	**Level 1** – 400 ppb for NO, SO_2, O_3, and 40 ppm for CO **Level 2** – 50 ppb NO, SO_2, O_3, and 5 ppm for CO **Level 3** – Zero	**Level 1 –** If instrument reponse is more than ±5% from standard values the analyzer is adjusted **Level 2 –** ±5 ppb for O_3, NO, SO_2 ±0.5 ppm for CO **Level 3 –** Zero ±3 ppb for O_3 Zero ±5 ppb for NO, SO_2 Zero ±0.5 ppm for CO
Gas Phase Tritration (GTP) for NO_X analyzer converter efficiency	Bi-Weekly	400 ppb NO with 350 ppb O_3	Converter efficiency >96%
Gas Phase Titration (GPT)	During Each Multipoint Calibration	**Level 1** – 400 ppb NO with 350 ppb O_3 **Level 2** - 400 ppb NO with 50 ppb O_3	Converter Efficiency greater than 96% or converter should be replaced
Multipoint Calibration, performed though instrument's sample	Quarterly	**Level 1** – 400 ppb for NO, SO_2, O_3, and 40 ppm for CO **Level 2** – 300 ppb NO, SO_2, O_3, and 30 ppm for CO **Level 3** – 200 ppb NO, SO_2, O_3, and 20 ppm for CO **Level 4** - 50 ppb NO, SO_2, O_3, and 5 ppm for CO **Level 5** –Zero	If instrument response is more than ± 3% from standard values analyzer is re-calibrated

3.0 INDIVIUDAL SITE AUDIT RESULTS

This section describes the audit results for each of the 10 sites. During the audit, audit data were recorded into formatted Excel data sheets that calculated percent difference from the known concentration values. In addition, an audit checklist was also reviewed for each site checking that the systems met specifications. The checklists (presented in Appendix B) aids in assessing the overall site conditions, including preventative maintenance, documentation, and overall system operation. In general, the audits followed US EPA guidelines for ambient air monitoring systems found in the following documents:

- Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II: Part 1, Ambient Air Quality Monitoring Program System Development, EPA-454/R-98-004, December 2008.
- Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV: Meteorological Measurements, EPA/600/R-94/038d, March 2008.
- Quality Assurance Handbook for Air Pollution Measurement Systems, Volume I: A Field Guide to Environmental Quality Assurances, EPA/600/R-94/038a, April 1994.

3.1 General Observations

All of the sites were very well maintained, the plumbing and electrical wiring were well designed and consequently easy to work on, and finally, the shelters were quite clean. All of the glass sampling manifolds were found to be free of dirt and debris and the sampling heads (PM_{10} and $PM_{2.5}$) were regularly cleaned and maintained.

There were a number of "best practices" that the network uses to help ensure quality. For instance, all operators carry hand-held PDA's to record operating information from each site during each site visit. These data are then downloaded at the main laboratory so that changes in instrument performance can be tracked and monitored. In addition, during each quarterly multipoint calibration, a tag containing this same information is affixed to each instrument showing instrument performance parameters. A photograph of one of these tags is shown in Figure 3-1. As this information appeared to go back at least one year, these tags allow an operator to very quickly determine if the current instrument performance has degraded (such as PMT voltage) since last calibration.

A review of the site operator logs showed that the operators were very good at documenting their on-site activities, entries were written in ink, cross-outs were properly done, entries were signed and dated, and usually the time in and out documented. The only deficiency noted with the log books was that while almost all entries had a starting time, finish times of the operator were more sporadic. A few operators were very reliable with start/finish times, but this small aspect of the

documentation could be improved. For instance, operator logs are needed to reproduce data or determine the extent of downtime. It needs to be noted that site operators call the main laboratory when they arrive and leave each site, so this information may be documented elsewhere.

Another best practice included control charting of the zero and span data for each analyzer in the sites. These data were kept at each site so the operator could quickly see if an analyzer's performance was different from previous results or if an analyzer's performance was slowly changing.

Overall, these 10 stations were well operated, the operators appeared to be well trained and were very knowledgeable about QA/QC procedures and, and appeared to care a lot about the quality of their work and clearly took pride in their jobs.

Further discussions and audit results from each of the ten individual sites are presented in the sections below.

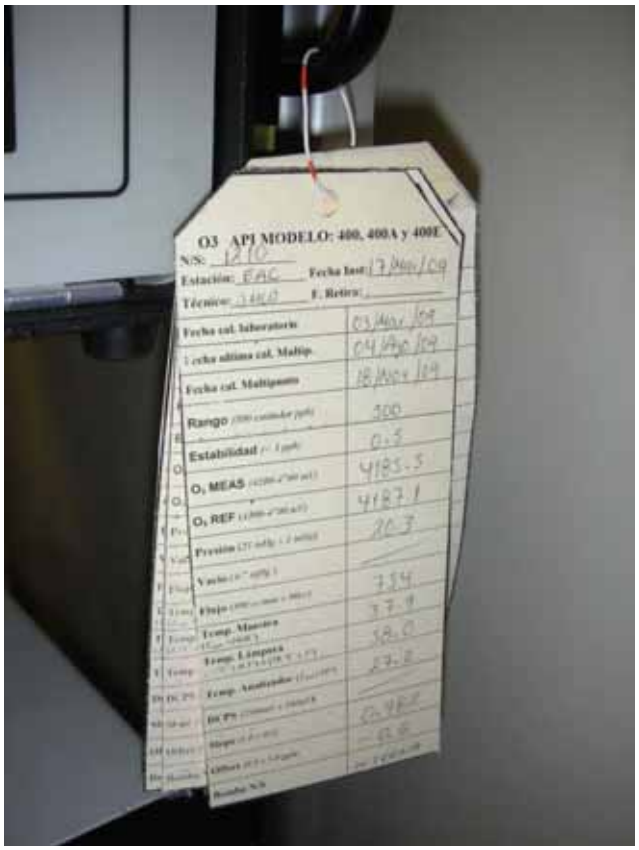

Figure 3-1. Photo of Instrument Information Tag

3.2 ENEP-ACATLAN (EAC) Site

This site was located at the campus of the National School of Professional Studies on the roof of the Odontology Clinic building. This was the first of the audited sites. Overall the site appeared well maintained and very clean. The audit results showed that the parameters CO (-0.6%), NO (6.4%), NO_x (6.9%), and SO_2 (9.3%) were all well within the audit objective of ± 15%. The ozone analyzer showed an average percent difference of -14.6%, which is within the average audit objective but two of the five points were outside that objective. In addition, the GPT showed a slightly lower than desirable NO_2 convertor efficiency skewed by one of the three values. In addition to the gas-phase instruments the site contained a TEOM 1400a PM_{10} analyzer. The total measured flow rate through the analyzer was 17.08 lpm, 2.3% higher than the design specification of 16.7 lpm and well within acceptable limits to maintain the impactor cut-point.

As this was the first site audited and the auditor had not previously used the Environics Model 6103 calibrator, certain nuisances of its operation may have resulted in the low recoveries for ozone and the GPT. Of the three GPT points, two indicated that the conversion was well within acceptable limits, but the third point was significantly outside the limit, which resulted in an average outside of the 96% conversion efficiency. This point may have been either miss-transcribed or the setting was improperly set. As the auditor believes that the issues with ozone at this site were likely caused by auditor error, no data are shown for the ozone and GPT are shown below.

It is recommended that during the next calibration, the ozone and GPT are checked to either confirm or refute these results. At this time specific corrective action is not recommended at this site. Sample results for each of the analyzers at this site are shown in Tables 3-1 to 3-3. A photo of this site is shown in Figure 3.2 below.

Table 3-1. Summary of Sulphur Dioxide (SO_2) Audit Results, EAC Site

SO_2 Input (ppm-v)	SO_2 Response (ppm-v)	Percent Difference[1]	SO_2 Analyzer Regression Data	
0.000	0.006	---	***Slope:***	0.9025
0.110	0.098	-11.1%	***Intercept:***	0.0029
0.220	0.201	-8.6%	***Correlation:***	0.9998
0.331	0.303	-8.5%		
0.442	0.402	-9.0%		

[1] **Objective ±15%**

Figure 3.2. Photo of EAC Site

Table 3-2. Summary of Carbon Monoxide (CO) Audit Results, EAC Site

CO Input (ppm-v)	CO Response (ppm-v)	Percent Difference[1]	CO Analyzer Regression Data	
0.0	0.0	---	***Slope:***	0.9911
11.2	11.2	0.0%	***Intercept:***	0.0400
22.4	22.3	-0.4%	***Correlation:***	1.0000
33.7	33.3	-1.2%		
44.9	44.6	-0.7%		

[1] **Objective ±15%**

Table 3-3. Summary of Nitrogen Oxides (NO_x) Audit Results, EAC Site

NO_X / NO Input (ppm-v)	Response		Percent Difference[1]		NO_x Analyzer Regression Data		
	NO_X (ppm-v)	NO (ppm-v)	NO_X	NO	Parameter	NO_X	NO
0.000	0.001	-0.001	---	---	***Slope:***	1.0557	1.0735
0.100	0.108	0.106	8.0%	5.8%	***Intercept:***	0.0020	-0.0016
0.200	0.214	0.212	7.2%	6.0%	***Correlation:***	1.0000	1.0000
0.300	0.321	0.320	6.8%	6.6%			
0.400	0.422	0.429	5.6%	7.2%			

[1] Objective ±15%

3.3 Tlalnepantla (TLA) Site

This site was located in a shed about 2 meters above ground level adjacent to a municipal water storage tank. This was an older site but still appeared well maintained and relatively clean. The audit results showed that all of the parameters were well within the average and individual audit objective of ± 15%. The average results for each of the analyzers were CO (-1.2%), NO (6.1%), NO_x (8.2%), O_3 (0.9%) and SO_2 (9.1%). The GPT showed that the NO_2 convertor efficiency was 98.2%.

The PM_{10} and $PM_{2.5}$ TEOM analyzers were not tested at this site due to safety and access issues. It was dark when this site was audited and the only way of getting to the roof was to climb the meteorological tower which was approximately ½ a meter from the roof. There are no corrective actions associated with this site. Audit results for each of the analyzers at this site are shown in Tables 3-4 to 3-9.

Table 3-4. Summary of Sulphur Dioxide (SO_2) Audit Results, TLA Site

SO_2 Input (ppm-v)	SO_2 Response (ppm-v)	Percent Difference[1]	SO_2 Analyzer Regression Data	
0.000	0.000	---	***Slope:***	0.9235
0.110	0.099	-10.4%	***Intercept:***	-0.0022
0.220	0.199	-9.5%	***Correlation:***	0.9999
0.331	0.301	-9.1%		
0.442	0.409	-7.5%		

[1] **Objective ±15%**

Table 3-5. Summary of Ozone (O_3) Audit Results, TLA Site

O_3 Input (ppm-v)	O_3 Response (ppm-v)	Percent Difference[1]	O_3 Analyzer Regression Data	
0.000	0.001	---	***Slope:***	0.9948
0.050	0.051	2.4%	***Intercept:***	0.0016
0.101	0.102	1.4%	***Correlation:***	1.0000
0.200	0.202	0.8%		
0.300	0.300	0.0%		
0.401	0.400	-0.2%		

[1] **Objective ±15%**

Table 3-6. Summary of Carbon Monoxide (CO) Audit Results, TLA Site

CO Input (ppm-v)	CO Response (ppm-v)	Percent Difference[1]	CO Analyzer Regression Data	
0.0	-0.1	---	***Slope:***	0.9938
11.2	10.9	-2.7%	***Intercept:***	-0.1001
22.4	22.3	-0.4%	***Correlation:***	1.0000
33.7	33.5	-0.6%		
44.9	44.4	-1.1%		

[1] **Objective ±15%**

Table 3-7. Summary of Nitrogen Oxides (NO_x) Audit Results, TLA Site

NO_X / NO Input (ppm-v)	Response		Percent Difference[1]		NO_x Analyzer Regression Data		
	NO_X (ppm-v)	NO (ppm-v)	NO_X	NO	Parameter	NO_X	NO
0.000	0.001	-0.003	---	---	***Slope:***	1.0764	1.0671
0.100	0.108	0.107	8.0%	7.0%	***Intercept:***	0.0013	-0.0022
0.250	0.275	0.263	10.0%	5.2%	***Correlation:***	0.9998	0.9997
0.350	0.372	0.366	6.3%	4.6%			
0.400	0.434	0.432	8.5%	8.0%			
0.450	0.486	0.476	8.0%	5.8%			

[1] **Objective ±15%**

Table 3-8. Summary of Nitrogen Oxides (NO_x) Audit Results, TLA Site

Gas Phase Titration					
Ozone Setting	Response		Corrected		NO Corrected
	NO_X	NO	NO_X	NO	
off	0.486	0.476	0.450	0.448	---
400	0.456	0.045	0.422	0.044	0.044
off	0.372	0.366	0.344	0.345	---
253	0.376	0.109	0.348	0.104	0.104
Off	0.275	0.263	0.254	0.248	---
150	0.275	0.118	0.254	0.113	0.113

Table 3-9. Summary of Nitrogen Oxides (NO_x) GPT Results, TLA Site

NO_2 Audit Data					
NO_2 Input (ppm-v)	NO_2 Response (ppm-v)	NO_2 Percent Difference	NO_2 Converted (ppm-v)	NO_2 Analyzer Regression Data	
0.000	0.004	---	---	***Slope:***	1.0064
0.135	0.157	16.3%	0.135	***Intercept:***	0.0135
0.241	0.267	10.8%	0.245	***Correlation:***	0.9980
0.404	0.411	1.7%	0.376	***Converter Efficiency***[1]	**98.2**

[1] **Acceptance Criteria >96%**

3.4 San Agustín (SAG) Site

The station is located inside an Ekto Shelter located on the roof of a health care center. The equipment and site were well maintained and very clean. The audit results showed that all of the parameters were well within the average and individual audit objective of ± 15%. The average results for each of the analyzers were CO (1.2%), NO (7.1%), NO_x (7.7%), O_3 (-4.9%) and SO_2 (8.3%). The GPT showed that the NO_2 convertor efficiency was 99.6%.

The Shelter had a Thermo Andersen $PM_{2.5}$ Beta Attenuation monitor and a TEOM Model 1400a PM_{10}. The flow rate through the PM_{10} sampler was 17.02 lpm and through the $PM_{2.5}$ was 16.59 lpm. Both values are well within specification for adequate impactor cut-points. A photo of this site is shown in Figure 3-3 below. There are no corrective actions associated with this site. Audit results for each of the analyzers at this site are shown in Tables 3-10 to 3-15.

Figure 3-3. Photo of SAG Site

Table 3-10. Summary of Sulphur Dioxide (SO_2) Audit Results, SAG Site

SO_2 Input (ppm-v)	SO_2 Response (ppm-v)	Percent Difference[1]	SO_2 Analyzer Regression Data	
0.000	0.000	---	***Slope:***	0.9566
0.110	0.096	-12.7%	***Intercept:***	-0.0058
0.220	0.200	-9.1%	***Correlation:***	0.9995
0.331	0.307	-7.3%		
0.442	0.423	-4.3%		

[1] **Objective ±15%**

Table 3-11. Summary of Ozone (O_3) Audit Results, SAG Site

O_3 Input (ppm-v)	O_3 Response (ppm-v)	Percent Difference[1]	O_3 Analyzer Regression Data	
0.000	0.001	---	***Slope:***	0.9740
0.050	0.045	-10.0%	***Intercept:***	-0.0016
0.100	0.094	-5.7%	***Correlation:***	0.9999
0.199	0.193	-3.0%		
0.300	0.291	-3.0%		
0.401	0.389	-3.0%		

[1] **Objective ±15%**

Table 3-12. Summary of Carbon Monoxide (CO) Audit Results, SAG Site

CO Input (ppm-v)	CO Response (ppm-v)	Percent Difference[1]	CO Analyzer Regression Data	
0.0	0.3	---	***Slope:***	1.0044
11.2	11.4	1.8%	***Intercept:***	0.2002
22.4	22.7	1.3%	***Correlation:***	1.0000
33.7	33.8	0.3%		
44.9	45.5	1.3%		

[1] **Objective ±15%**

Table 3-13. Summary of Nitrogen Oxides (NO_x) Audit Results, SAG Site

NO_X / NO Input (ppm-v)	Response		Percent Difference[1]		NO_x Analyzer Regression Data		
	NO_X (ppm-v)	NO (ppm-v)	NO_X	NO	Parameter	NO_X	NO
0.000	0.002	0.001	---	---	***Slope:***	1.0639	1.0672
0.050	0.054	0.054	8.0%	8.0%	***Intercept:***	0.0024	0.0007
0.150	0.164	0.159	9.3%	6.0%	***Correlation:***	1.0000	1.0000
0.250	0.269	0.269	7.6%	7.6%			
0.350	0.375	0.375	7.1%	7.1%			
0.450	0.480	0.480	6.7%	6.7%			

[1] **Objective ±15%**

Table 3-14. Summary of Nitrogen Oxides (NO_x) Audit Results, SAG Site

Gas Phase Titration					
Ozone Setting	Response		Corrected		NO Corrected
	NO_X	NO	NO_X	NO	
off	0.480	0.480	0.449	0.449	---
400	0.474	0.099	0.443	0.092	0.092
off	0.375	0.375	0.350	0.351	---
300	0.376	0.089	0.351	0.083	0.083
Off	0.269	0.269	0.251	0.251	---
200	0.269	0.083	0.251	0.077	0.077

Table 3-15. Summary of Nitrogen Oxides (NO_x) GPT Results, SAG Site

NO_2 Audit Data					
NO_2 Input (ppm-v)	NO_2 Response (ppm-v)	NO_2 Percent Difference	NO_2 Converted (ppm-v)	NO_2 Analyzer Regression Data	
0.000	0.001	---	---	***Slope:***	1.0517
0.174	0.186	6.9%	0.174	***Intercept:***	0.0022
0.268	0.287	7.1%	0.269	***Correlation:***	0.9999
0.357	0.375	5.0%	0.351	***Converter Efficiency***[1]	**99.6**

[1] **Acceptance Criteria >96%**

3.5 Merced (MER) Site

The station is located inside a shed located on the roof of a health care center. The shelter was older but the equipment and site were well maintained and relatively clean. There were a number of manual PM samplers at this site including TSP, PM_{10} and FRM $PM_{2.5}$. The audit results showed that all of the parameters were well within the average and individual audit objective of ± 15% except SO_2. The average results for the analyzers were CO (-0.1%), NO (7.1%), NO_x (3.1%), O_3 (-0.5%) and SO_2 (-13.9%). While the average percent difference for SO_2 was within the audit objective, one of the four SO_2 points was slightly outside of the individual value objective of ±15% at -17.8%. In general, this was slow to respond and should be considered for maintenance. While the SO_2 parameter is generally slower to respond than other instruments, if the instrument has not reached 95% of the input value within 5 minutes, there is a risk that the instrument is not able to measure and record transitory elevations in ambient concentrations. The GPT showed good NO_2 convertor efficiency at 98.6%.

The Shelter had a TEOM 1400a-FDMS 8500 $PM_{2.5}$ monitor and a TEOM Model 1400a PM_{10}. The flow rate through both samplers was well within specification for adequate impactor cut-points. A photo of this site is shown in Figure 3-4 below. Other than reviewing the SO_2 response and response time, there are no other corrective actions associated with this site. Audit results for each of the analyzers at this site are shown in Tables 3-16 to 3-21.

Figure 3-4. Photo of MER Site

Table 3-16. Summary of Sulphur Dioxide (SO_2) Audit Results, MER Site

SO_2 Input (ppm-v)	SO_2 Response (ppm-v)	Percent Difference[1]	SO_2 Analyzer Regression Data	
0.000	0.002	---	***Slope:***	0.8514
0.110	0.098	-10.9%	***Intercept:***	0.0013
0.220	0.189	-14.1%	***Correlation:***	0.9989
0.331	0.272	-17.8%		
0.442	0.385	-12.9%		

[1] **Objective ±15%**

Table 3-17. Summary of Ozone (O_3) Audit Results, MER Site

O_3 Input (ppm-v)	O_3 Response (ppm-v)	Percent Difference[1]	O_3 Analyzer Regression Data	
0.000	0.000	---	***Slope:***	0.9783
0.049	0.051	3.0%	***Intercept:***	0.0013
0.100	0.100	-0.2%	***Correlation:***	1.0000
0.200	0.197	-1.5%		
0.300	0.294	-2.0%		
0.400	0.393	-1.8%		

[1] **Objective ±15%**

Table 3-18. Summary of Carbon Monoxide (CO) Audit Results, MER Site

CO Input (ppm-v)	CO Response (ppm-v)	Percent Difference[1]	CO Analyzer Regression Data	
0.0	0.3	---	***Slope:***	0.9890
11.2	11.2	0.0%	***Intercept:***	0.2717
22.4	22.5	0.4%	***Correlation:***	1.0000
33.7	33.7	0.0%		
44.9	44.6	-0.7%		

[1] **Objective ±15%**

Table 3-19. Summary of Nitrogen Oxides (NO_x) Audit Results, MER Site

NO_X / NO Input (ppm-v)	Response		Percent Difference[1]		NO_x Analyzer Regression Data		
	NO_X (ppm-v)	NO (ppm-v)	NO_X	NO	Parameter	NO_X	NO
0.000	0.001	-0.001	---	---	***Slope:***	1.0210	1.0021
0.050	0.057	0.054	14.0%	7.4%	***Intercept:***	0.0062	0.0028
0.150	0.162	0.157	8.0%	4.7%	***Correlation:***	0.9996	0.9998
0.250	0.267	0.253	6.8%	1.2%			
0.350	0.367	0.358	4.9%	2.3%			
0.450	0.459	0.449	2.0%	-0.2%			

[1] **Objective ±15%**

Table 3-20. Summary of Nitrogen Oxides (NO_x) Audit Results, MER Site

Gas Phase Titration					
Ozone Setting	Response		Corrected		NO Corrected
	NO_X	NO	NO_X	NO	
off	0.459	0.449	0.443	0.445	---
400	0.448	0.043	0.433	0.040	0.040
off	0.367	0.358	0.353	0.354	---
300	0.367	0.067	0.353	0.064	0.064
Off	0.267	0.253	0.255	0.250	---
200	0.263	0.066	0.252	0.063	0.063

Table 3-21. Summary of Nitrogen Oxides (NO_x) GPT Results, MER Site

NO_2 Audit Data					
NO_2 Input (ppm-v)	NO_2 Response (ppm-v)	NO_2 Percent Difference	NO_2 Converted (ppm-v)	NO_2 Analyzer Regression Data	
0.000	0.003	---	---	***Slope:***	0.9971
0.187	0.197	5.3%	0.184	***Intercept:***	0.0063
0.290	0.300	3.4%	0.290	***Correlation:***	0.9996
0.405	0.405	0.0%	0.395	***Converter Efficiency***[1]	98.6%

[1] **Acceptance Criteria >96%**

3.6 UAM Iztapala (UIZ) Site

This station is located inside an Ekto Shelter on the top of a third floor building at Universidad Autónoma Metropolitana Campus. The shelter and the equipment were extremely well maintained and very clean. The audit results showed that all of the parameters were well within the average and individual audit objective of ± 15%. The average results for the analyzers were CO (-4.5%), NO (8.7%), NO_x (8.9%), O_3 (2.0%) and SO_2 (-4.0%). The GPT showed good NO_2 convertor efficiency at 97.1%.

The site was equipped with a Thermo Andersen $PM_{2.5}$ Beta Attenuation monitor. The flow rate through the sampler was 16.65 lpm, a value well within specification for adequate impactor cut-points. A photo of this site is shown in Figure 3-5 below. There are no corrective actions associated with this site. Audit results for each of the analyzers at this site are shown in Tables 3-22 to 3-27.

Figure 3-5. Photo of UIZ Site

Table 3-22. Summary of Sulphur Dioxide (SO_2) Audit Results, UIZ Site

SO_2 Input (ppm-v)	SO_2 Response (ppm-v)	Percent Difference[1]	SO_2 Analyzer Regression Data	
0.000	0.003	---	***Slope:***	0.9633
0.110	0.106	-3.6%	***Intercept:***	0.0003
0.220	0.208	-5.5%	***Correlation:***	0.9998
0.331	0.318	-3.9%		
0.442	0.429	-2.9%		

[1] **Objective ±15%**

Table 3-23. Summary of Ozone (O_3) Audit Results, UIZ Site

O_3 Input (ppm-v)	O_3 Response (ppm-v)	Percent Difference[1]	O_3 Analyzer Regression Data	
0.000	0.001	---	***Slope:***	1.0009
0.050	0.053	6.0%	***Intercept:***	0.0018
0.100	0.102	2.0%	***Correlation:***	1.0000
0.200	0.202	1.0%		
0.300	0.302	0.7%		
0.400	0.402	0.5%		

[1] **Objective ±15%**

Table 3-24. Summary of Carbon Monoxide (CO) Audit Results, UIZ Site

CO Input (ppm-v)	CO Response (ppm-v)	Percent Difference[1]	CO Analyzer Regression Data	
0.0	-0.1	---	***Slope:***	0.9599
11.2	10.7	-4.5%	***Intercept:***	-0.1206
22.4	21.4	-4.5%	***Correlation:***	0.9999
33.7	31.9	-5.3%		
44.9	43.2	-3.8%		

[1] **Objective ±15%**

Table 3-25. Summary of Nitrogen Oxides (NO_x) Audit Results, UIZ Site

NO_X / NO Input (ppm-v)	Response		Percent Difference[1]		NO_x Analyzer Regression Data		
	NO_X (ppm-v)	NO (ppm-v)	NO_X	NO	Parameter	NO_X	NO
0.000	0.002	0.002	---	---	***Slope:***	1.0804	1.0808
0.050	0.056	0.055	12.0%	10.0%	***Intercept:***	0.0010	0.0011
0.150	0.160	0.162	6.7%	8.0%	***Correlation:***	0.9999	0.9999
0.250	0.274	0.274	9.6%	9.6%			
0.350	0.376	0.376	7.4%	7.4%			
0.451	0.490	0.490	8.6%	8.6%			

[1] **Objective ±15%**

Table 3-26. Summary of Nitrogen Oxides (NO_x) Audit Results, UIZ Site

Gas Phase Titration					
Ozone Setting	**Response**		**Corrected**		**NO Corrected**
	NO_X	**NO**	**NO_X**	**NO**	
off	0.490	0.490	0.453	0.452	---
400	0.470	0.120	0.434	0.110	0.110
off	0.376	0.376	0.347	0.347	---
300	0.375	0.082	0.346	0.075	**0.075**
Off	0.274	0.274	0.253	0.253	---
200	0.269	0.075	0.248	0.068	**0.068**

Table 3-27. Summary of Nitrogen Oxides (NO_x) GPT Results, UIZ Site

NO_2 Audit Data					
NO_2 Input (ppm-v)	**NO_2 Response (ppm-v)**	**NO_2 Percent Difference**	**NO_2 Converted (ppm-v)**	**NO_2 Analyzer Regression Data**	
0.000	0.000	---	---	***Slope:***	1.0382
0.185	0.194	4.9%	0.180	***Intercept:***	0.0019
0.272	0.293	7.7%	0.271	***Correlation:***	0.9991
0.342	0.350	2.3%	0.323	***Converter Efficiency***[1]	97.1%

[1] **Acceptance Criteria >96%**

3.7 Iztacalco (IZT) Site

This station is in a low-income residential area housed in a Shelter One shelter located on the top of the second floor of a health center. The shelter and equipment were well maintained and very clean. The audit results showed that all of the parameters were well within the average and individual audit objective of ± 15% except SO_2. The average results for the analyzers were CO (-1.0%), NO (5.3%), NO_x (6.9%), O_3 (1.8%) and SO_2 (-18.9%). The average percent difference as well as three out of four individual audit points for SO_2 was outside the audit objective. This instrument was extremely slow to respond and needs to be carefully checked. The auditor allowed over 20 minutes for one calibration point to stabilize, and the instrument was still rising at about 1 ppb per minute. While SO_2 instruments are generally slower to respond than other instruments, if the instrument cannot reach 95% of the input value within 5 minutes, there is a risk that the instrument is not able to measure and record transitory elevations in ambient concentrations. So while this instrument may have eventually calibrated if given unlimited time, there is a response time issue that needs to considered with any instrument, and this analyzer clearly has response time issues. The GPT showed good NO_2 convertor efficiency at 101%.

The Shelter had a Thermo Andersen PM_{10} Beta Attenuation monitor. The flow rate through the sampler was well within specification for adequate impactor cut-points at 17.04 lpm. A photo of this site is shown in Figure 3-6 below. Other than reviewing the SO_2 response, and response time, there are no other corrective actions associated with this site. Audit results for each of the analyzers at this site are shown in Tables 3-28 to 3-33.

Figure 3-6. Photo of the IZT Site

Table 3-28. Summary of Sulphur Dioxide (SO_2) Audit Results, IZT Site

SO_2 Input (ppm-v)	SO_2 Response (ppm-v)	Percent Difference[1]	SO_2 Analyzer Regression Data	
0.000	0.005	---	***Slope:***	0.8826
0.110	0.091	-17.3%	***Intercept:***	-0.0107
0.220	0.153	-30.3%	***Correlation:***	0.9893
0.331	0.266	-19.6%		
0.442	0.405	-8.4%		

[1] **Objective ±15%**

Table 3-29. Summary of Ozone (O_3) Audit Results, IZT Site

O_3 Input (ppm-v)	O_3 Response (ppm-v)	Percent Difference[1]	O_3 Analyzer Regression Data	
0.000	0.000	---	***Slope:***	1.0060
0.050	0.052	4.0%	***Intercept:***	0.0011
0.102	0.104	2.0%	***Correlation:***	1.0000
0.199	0.202	1.5%		
0.299	0.302	1.0%		
0.400	0.403	0.8%		

[1] **Objective ±15%**

Table 3-30. Summary of Carbon Monoxide (CO) Audit Results, IZT Site

CO Input (ppm-v)	CO Response (ppm-v)	Percent Difference[1]	CO Analyzer Regression Data	
0.0	0.1	---	***Slope:***	0.9956
11.2	10.9	-2.6%	***Intercept:***	-0.0383
22.4	22.3	-0.3%	***Correlation:***	1.0000
33.7	33.6	-0.3%		
44.9	44.6	-0.6%		

[1] **Objective ±15%**

Table 3-31. Summary of Nitrogen Oxides (NO_x) Audit Results, IZT Site

NO_X / NO Input (ppm-v)	Response		Percent Difference[1]		NO_x Analyzer Regression Data		
	NO_X (ppm-v)	NO (ppm-v)	NO_X	NO	Parameter	NO_X	NO
0.000	0.003	-0.001	---	---	***Slope:***	1.0564	1.0602
0.050	0.055	0.052	10.0%	4.0%	***Intercept:***	0.0020	-0.0010
0.150	0.160	0.159	6.7%	6.0%	***Correlation:***	1.0000	1.0000
0.250	0.263	0.262	5.2%	4.8%			
0.350	0.372	0.370	6.3%	5.7%			
0.450	0.479	0.477	6.4%	6.0%			

[1] **Objective ±15%**

Table 3-32. Summary of Nitrogen Oxides (NO_x) Audit Results, IZT Site

Gas Phase Titration					
Ozone Setting	Response		Corrected		NO Corrected
	NO_X	NO	NO_X	NO	
Off	0.479	0.477	0.452	0.451	---
400	0.477	0.077	0.450	0.074	**0.074**
Off	0.372	0.370	0.350	0.350	---
300	0.373	0.072	0.351	0.069	**0.069**
Off	0.263	0.262	0.247	0.248	---
200	0.269	0.066	0.253	0.063	**0.063**

Table 3-33. Summary of Nitrogen Oxides (NO_x) GPT Results, IZT Site

NO_2 Audit Data					
NO_2 Input (ppm-v)	NO_2 Response (ppm-v)	NO_2 Percent Difference	NO_2 Converted (ppm-v)	NO_2 Analyzer Regression Data	
0.000	0.004	---	---	***Slope:***	1.0502
0.185	0.203	9.7%	0.191	***Intercept:***	0.0057
0.281	0.301	7.1%	0.282	***Correlation:***	0.9999
0.377	0.400	6.1%	0.375	***Converter Efficiency***[1]	**101.0%**

[1] **Acceptance Criteria >96%**

3.8 Santa Ursula (SUR) Site

This station is in a residential area at the south of Mexico City housed in a shed on the top of a health center**.** The shelter and equipment were well maintained and very clean. The audit results showed that all of the parameters were well within the average and individual audit objective of ± 15% except SO_2. The average results for the analyzers were CO (-4.4%), NO (4.7%), NO_x (5.7%), O_3 (-2.5%) and SO_2 (-13.2%). The GPT showed good NO_2 convertor efficiency at 100.4%.

For SO_2, the average percent difference was within the ± 15% audit objective, but two of the four individual audit points were slightly outside of the audit objective (15.4%). This instrument (an older API Model 100) appeared to have a very slow response plus a problem with the display value versus the PMT value. With the instrument sampling the audit gas, the PMT value would escalate, but the ppm value would remain the same or barely rise. When you pressed the {CALM} button on the front panel (the method used by the operators to calibrate the instrument) the ppm reading would jump suddenly to be more in line with the PMT value. For example, when checking the 330 ppb audit point, the PMT reading went from 1900 mv to 2450 mv but the concentration display only increased 3 ppb (194 to 197). When the {CALM} button was pressed the display reading went to 259 ppb. This very slow response of the concentration display may produce bias in transient SO_2 concentrations. Since this was occurring during the audit which simulates ambient values, this suggests that changes in ambient concentration could be significantly biased in the same manner the audit values were (e.g., the PMT values increase but the ppb readout does not). The response time issue needs to addressed and this instrument should be evaluated to determine what is causing this unusual response.

The shelter was equipped with a TEOM PM_{10} analyzer. The flow rate through the sampler was well within specification for adequate impactor cut-points at 16.65 lpm. This is slightly lower than other TEOM flow rates which were typically 17 lpm. It was noted that the Auxiliary filter was very dark which may have been causing the very slight flow reduction. A photo of this site is shown in Figure 3-7 below. Other than reviewing the SO_2 response and response time, there are no other corrective actions associated with this site. Audit results for each of the analyzers at this site are shown in Tables 3-34 to 3-39.

Figure 3-7. Photo of the SUR Site

Table 3-34. Summary of Sulphur Dioxide (SO_2) Audit Results, SUR Site

SO_2 Input (ppm-v)	SO_2 Response (ppm-v)	Percent Difference[1]	SO_2 Analyzer Regression Data	
0.000	-0.002	---	***Slope:***	0.8443
0.110	0.099	-10.0%	***Intercept:***	0.0027
0.220	0.194	-11.8%	***Correlation:***	0.9996
0.331	0.280	-15.4%		
0.442	0.374	-15.4%		

[1] **Objective ±15%**

Table 3-35. Summary of Ozone (O_3) Audit Results, SUR Site

O_3 Input (ppm-v)	O_3 Response (ppm-v)	Percent Difference[1]	O_3 Analyzer Regression Data	
0.000	0.001	---	***Slope:***	0.9683
0.050	0.049	-2.0%	***Intercept:***	0.0016
0.100	0.099	-0.7%	***Correlation:***	1.0000
0.199	0.195	-2.0%		
0.299	0.293	-2.0%		
0.400	0.387	-3.3%		

[1] **Objective ±15%**

Table 3-36. Summary of Carbon Monoxide (CO) Audit Results, SUR Site

CO Input (ppm-v)	CO Response (ppm-v)	Percent Difference[1]	CO Analyzer Regression Data	
0.0	-0.2	---	***Slope:***	0.9588
11.2	10.8	-3.4%	***Intercept:***	-0.1327
22.4	21.4	-4.5%	***Correlation:***	0.9998
33.7	31.7	-5.9%		
44.9	43.2	-3.8%		

[1] **Objective ±15%**

Table 3-37. Summary of Nitrogen Oxides (NO_x) Audit Results, SUR Site

NO_X / NO Input (ppm-v)	Response		Percent Difference[1]		NO_x Analyzer Regression Data		
	NO_X (ppm-v)	NO (ppm-v)	NO_X	NO	Parameter	NO_X	NO
0.000	0.004	0.002	---	---	***Slope:***	1.0049	1.0033
0.050	0.056	0.055	12.0%	10.0%	***Intercept:***	0.0072	0.0057
0.150	0.162	0.158	8.0%	5.3%	***Correlation:***	0.9998	0.9996
0.250	0.261	0.263	4.4%	5.2%			
0.350	0.361	0.361	3.1%	3.1%			
0.450	0.455	0.450	1.1%	0.0%			

[1] **Objective ±15%**

Table 3-38. Summary of Nitrogen Oxides (NO_x) Audit Results, SUR Site

Gas Phase Titration					
Ozone Setting	Response		Corrected		NO Corrected
	NO_X	NO	NO_X	NO	
off	0.455	0.450	0.446	0.443	---
400	0.450	0.066	0.441	0.060	**0.060**
off	0.361	0.361	0.352	0.354	---
300	0.359	0.072	0.350	0.066	**0.066**
Off	0.261	0.263	0.253	0.256	---
200	0.267	0.068	0.259	0.062	**0.062**

Table 3-39. Summary of Nitrogen Oxides (NO_x) GPT Results, SUR Site

NO_2 Audit Data					
NO_2 Input (ppm-v)	NO_2 Response (ppm-v)	NO_2 Percent Difference	NO_2 Converted (ppm-v)	NO_2 Analyzer Regression Data	
0.000	0.002	---	---	***Slope:***	0.9933
0.194	0.199	2.6%	0.200	***Intercept:***	0.0033
0.288	0.287	-0.3%	0.286	***Correlation:***	0.9999
0.383	0.384	0.3%	0.378	***Converter Efficiency***[1]	**100.4%**

[1] **Acceptance Criteria >96%**

3.9 Pedregal (PED) Site

This station is in a high-income residential area in southwest Mexico City housed in a shed on the top of the second floor of an elementary school. The shelter was very old and cramped but the equipment was well maintained. An API calibrator and air source have been installed at this site for future calibrations, but the installation was not complete or operable at the time of the audit. The audit results showed that all of the parameters were well within the average and individual audit objective of ± 15%. The average results for the analyzers were CO (-1.5%), NO (3.3%), NO_x (4.5%), O_3 (-0.4%) and SO_2 (-5.4%). The GPT showed good NO_2 convertor efficiency at 101%.

The shelter was equipped with a TEOM PM_{10} analyzer. The flow rate through the sampler was well within specification for adequate impactor cut-points at 16.97 lpm. A photo of this site is shown in Figure 3-8 below. There are no corrective actions associated with this site. Audit results for each of the analyzers at this site are shown in Tables 3-40 to 3-45.

Figure 3-8. Photo of PED Site

Table 3-40. Summary of Sulphur Dioxide (SO_2) Audit Results, PED Site

SO_2 Input (ppm-v)	SO_2 Response (ppm-v)	Percent Difference[1]	SO_2 Analyzer Regression Data	
0.000	0.000	---	***Slope:***	0.9339
0.110	0.104	-5.5%	***Intercept:***	0.0020
0.220	0.210	-4.5%	***Correlation:***	0.9997
0.331	0.316	-4.5%		
0.442	0.410	-7.2%		

[1] **Objective ±15%**

Table 3-41. Summary of Ozone (O_3) Audit Results, PED Site

O_3 Input (ppm-v)	O_3 Response (ppm-v)	Percent Difference[1]	O_3 Analyzer Regression Data	
0.000	0.003	---	***Slope:***	0.9707
0.049	0.050	2.0%	***Intercept:***	0.0031
0.099	0.100	1.5%	***Correlation:***	1.0000
0.200	0.198	-1.0%		
0.300	0.294	-2.0%		
0.400	0.391	-2.3%		

[1] **Objective ±15%**

Table 3-42. Summary of Carbon Monoxide (CO) Audit Results, PED Site

CO Input (ppm-v)	CO Response (ppm-v)	Percent Difference[1]	CO Analyzer Regression Data	
0.0	0.1	---	***Slope:***	0.9855
11.2	10.9	-2.6%	***Intercept:***	0.0294
22.4	22.2	-1.1%	***Correlation:***	0.9999
33.7	33.5	-0.6%		
44.9	44.1	-1.8%		

[1] **Objective ±15%**

Table 3-43. Summary of Nitrogen Oxides (NO_x) Audit Results, PED Site

NO_X / NO Input (ppm-v)	Response		Percent Difference[1]		NO_x Analyzer Regression Data		
	NO_X (ppm-v)	NO (ppm-v)	NO_X	NO	Parameter	NO_X	NO
0.000	0.000	0.000	---	---	***Slope:***	1.0364	1.0460
0.050	0.053	0.051	6.0%	2.0%	***Intercept:***	0.0010	-0.0018
0.150	0.158	0.156	5.3%	4.0%	***Correlation:***	1.0000	0.9999
0.250	0.259	0.255	3.6%	2.0%			
0.350	0.363	0.362	3.7%	3.4%			
0.450	0.468	0.473	4.0%	5.1%			

[1] **Objective ±15%**

Table 2-44. Summary of Nitrogen Oxides (NO_x) Audit Results, PED Site

Gas Phase Titration					
Ozone Setting	Response		Corrected		NO Corrected
	NO_X	NO	NO_X	NO	
off	0.468	0.473	0.451	0.454	---
400	0.477	0.088	0.459	0.086	0.086
off	0.363	0.362	0.349	0.348	---
300	0.364	0.074	0.350	0.072	**0.072**
Off	0.259	0.255	0.249	0.245	---
200	0.260	0.066	0.250	0.065	**0.065**

Table 2-45. Summary of Nitrogen Oxides (NO_x) GPT Results, PED Site

NO_2 Audit Data					
NO_2 Input (ppm-v)	NO_2 Response (ppm-v)	NO_2 Percent Difference	NO_2 Converted (ppm-v)	NO_2 Analyzer Regression Data	
0.000	0.001	---	---	***Slope:***	1.0524
0.180	0.194	7.8%	**0.181**	***Intercept:***	0.0016
0.276	0.290	5.1%	**0.277**	***Correlation:***	0.9999
0.368	0.389	5.7%	**0.376**	***Converter Efficiency***[1]	**101.0%**

[1] **Acceptance Criteria >96%**

3.10 Xalostoc (XAL) Site

This station is in an industrial/commercial/residential area. The site is in a shed on the back lot of a car dealership. The exposure around the site is partially blocked by surrounding buildings. The shelter was very old and cramped but the equipment was well maintained. The audit results showed that all of the parameters were well within the average and individual audit objective of ± 15%. The average results for the analyzers were CO (-0.8%), NO (-0.9%), NO_x (-2.7%), O_3 (-0.4%) and SO_2 (-5.0%). The GPT showed good NO_2 convertor efficiency at 99.4%.

The shelter was equipped with a TEOM PM_{10} analyzer. The flow rate through the sampler was well within specification for adequate impactor cut-points at 16.98 lpm. A photo of this site is shown in Figure 3-9 below. There are no corrective actions associated with this site. Audit results for each of the analyzers at this site are shown in Tables 3-46 to 3-51.

Figure 3-9. Photo of the XAL Site

Table 3-46. Summary of Sulphur Dioxide (SO_2) Audit Results, XAL Site

SO_2 Input (ppm-v)	SO_2 Response (ppm-v)	Percent Difference[1]	SO_2 Analyzer Regression Data	
0.000	0.002	---	***Slope:***	0.9619
0.110	0.102	-7.3%	***Intercept:***	-0.0010
0.220	0.209	-5.0%	***Correlation:***	0.9999
0.331	0.317	-4.2%		
0.441	0.425	-3.6%		

[1] **Objective ±15%**

Table 3-47. Summary of Ozone (O_3) Audit Results, XAL Site

O_3 Input (ppm-v)	O_3 Response (ppm-v)	Percent Difference[1]	O_3 Analyzer Regression Data	
0.002	0.003	---	***Slope:***	0.9718
0.052	0.054	3.5%	***Intercept:***	0.0024
0.100	0.100	0.0%	***Correlation:***	1.0000
0.200	0.197	-1.5%		
0.300	0.295	-1.7%		
0.400	0.390	-2.5%		

[1] **Objective ±15%**

Table 3-48. Summary of Carbon Monoxide (CO) Audit Results, XAL Site

CO Input (ppm-v)	CO Response (ppm-v)	Percent Difference[1]	CO Analyzer Regression Data	
0.0	0.0	---	***Slope:***	0.9837
11.2	11.1	-0.4%	***Intercept:***	0.1336
22.4	22.3	-0.4%	***Correlation:***	1.0000
33.7	33.5	-0.7%		
44.9	44.1	-1.8%		

[1] **Objective ±15%**

Table 3-49. Summary of Nitrogen Oxides (NO_x) Audit Results, XAL Site

NO_X / NO Input (ppm-v)	Response		Percent Difference[1]		NO_x Analyzer Regression Data		
	NO_X (ppm-v)	NO (ppm-v)	NO_X	NO	Parameter	NO_X	NO
0.000	0.002	0.000	---	---	***Slope:***	0.9745	1.0104
0.050	0.049	0.049	-3.0%	-1.6%	***Intercept:***	0.0004	-0.0030
0.150	0.146	0.149	-2.7%	-0.7%	***Correlation:***	0.9999	0.9992
0.250	0.244	0.244	-2.4%	-2.4%			
0.350	0.338	0.341	-3.4%	-2.6%			
0.450	0.442	0.462	-1.8%	2.7%			

[1] **Objective ±15%**

Table 3-50. Summary of Nitrogen Oxides (NO_x) Audit Results, XAL Site

Gas Phase Titration					
Ozone Setting	Response		Corrected		NO Corrected
	NO_X	NO	NO_X	NO	
off	0.442	0.462	0.453	0.460	---
400	0.441	0.078	0.452	0.080	0.080
off	0.338	0.341	0.346	0.340	---
300	0.337	0.061	0.345	0.063	**0.063**
Off	0.244	0.244	0.250	0.244	---
200	0.242	0.056	0.248	0.058	**0.058**

Table 3-51. Summary of Nitrogen Oxides (NO_x) GPT Results, XAL Site

NO_2 Audit Data					
NO_2 Input (ppm-v)	NO_2 Response (ppm-v)	NO_2 Percent Difference	NO_2 Converted (ppm-v)	NO_2 Analyzer Regression Data	
0.000	0.002	---	---	***Slope:***	0.9561
0.186	0.186	0.0%	**0.184**	***Intercept:***	0.0053
0.277	0.276	-0.4%	**0.276**	***Correlation:***	0.9994
0.380	0.363	-4.5%	**0.379**	***Converter Efficiency***[1]	**99.4**

[1] **Acceptance Criteria >96%**

3-11 Ciudad de Mexico Air Monitoring Laboratory (LAB) Site

The air monitoring laboratory maintains a series of analyzers used as reference instruments and are not being used to monitor air quality. The audit results showed that all of the parameters were well within the average and individual audit objective of ± 15%. The average results for the analyzers were CO (-1.2%), NO (6.2%), NO_x (7.1%), O_3 (-0.9%) and SO_2 (-1.8%). The GPT showed good NO_2 convertor efficiency at 98.5%. There are no corrective actions associated with this site. Audit results for each of the analyzers at this site are shown in Tables 3-52 to 3-57.

Table 3-52. Summary of Sulphur Dioxide (SO_2) Audit Results, LAB Site

SO_2 Input (ppm-v)	SO_2 Response (ppm-v)	Percent Difference[1]	SO_2 Analyzer Regression Data	
0.000	0.000	---	***Slope:***	0.9755
0.110	0.108	-1.8%	***Intercept:***	0.0011
0.220	0.217	-1.4%	***Correlation:***	0.9999
0.331	0.326	-1.4%		
0.441	0.429	-2.7%		

[1] **Objective ±15%**

Table 3-53. Summary of Ozone (O_3) Audit Results, LAB Site

O_3 Input (ppm-v)	O_3 Response (ppm-v)	Percent Difference[1]	O_3 Analyzer Regression Data	
0.002	0.000	---	***Slope:***	0.9883
0.050	0.050	0.6%	***Intercept:***	-0.0004
0.100	0.099	-1.3%	***Correlation:***	1.0000
0.200	0.198	-1.2%		
0.298	0.295	-1.1%		
0.400	0.394	-1.5%		

[1] **Objective ±15%**

Table 3-54. Summary of Carbon Monoxide (CO) Audit Results, LAB Site

CO Input (ppm-v)	CO Response (ppm-v)	Percent Difference[1]	CO Analyzer Regression Data	
0.0	0.0	---	***Slope:***	0.9838
11.2	11.2	0.2%	***Intercept:***	0.0478
22.4	22.1	-1.3%	***Correlation:***	0.9999
33.7	32.9	-2.4%		
44.9	44.4	-1.1%		

[1] **Objective ±15%**

Table 3-55. Summary of Nitrogen Oxides (NO_x) Audit Results, LAB Site

NO_X / NO Input (ppm-v)	Response		Percent Difference[1]		NO_x Analyzer Regression Data		
	NO_X (ppm-v)	NO (ppm-v)	NO_X	NO	Parameter	NO_X	NO
0.000	0.000	0.000	---	---	***Slope:***	1.0838	1.0790
0.050	0.053	0.052	5.4%	4.2%	***Intercept:***	-0.0015	-0.0021
0.150	0.161	0.158	7.3%	5.3%	***Correlation:***	0.9999	0.9999
0.250	0.267	0.266	6.8%	6.4%			
0.350	0.376	0.374	7.4%	6.9%			
0.450	0.489	0.486	8.7%	8.0%			

[1] **Objective ±15%**

Table 3-56. Summary of Nitrogen Oxides (NO_x) Audit Results, LAB Site

Gas Phase Titration					
Ozone Setting	Response		Corrected		NO Corrected
	NO_X	NO	NO_X	NO	
off	0.489	0.486	0.453	0.452	---
400	0.471	0.073	0.436	0.069	**0.069**
off	0.376	0.374	0.348	0.349	---
300	0.374	0.080	0.346	0.076	**0.076**
Off	0.267	0.266	0.248	0.249	---
200	0.268	0.073	0.249	0.069	**0.069**

Table 3-57. Summary of Nitrogen Oxides (NO_x) GPT Results, LAB Site

NO_2 Audit Data					
NO_2 Input (ppm-v)	NO_2 Response (ppm-v)	NO_2 Percent Difference	NO_2 Converted (ppm-v)	NO_2 Analyzer Regression Data	
0.000	0.000	---	---	***Slope:***	1.0449
0.180	0.195	8.4%	0.181	***Intercept:***	0.0036
0.273	0.294	7.7%	0.271	***Correlation:***	1.0449
0.383	0.398	4.0%	0.366	***Converter Efficiency***[1]	**98.5%**

[1] **Acceptance Criteria >96%**

4.0 RESPONSE REQUIREMENTS

This section summarizes the primary and secondary concerns and observations from the audit. Table 4-1 presents a summary of the audit observations and concerns. Primary concerns are those that may affect the ability of the measurement system to produce data within the data quality objectives (DQOs) of the program while secondary concerns are minor issues that likely do not have any impact on the DQOs. Concerns or observations identified in this audit report require a written response by the appropriate personnel assigned to each portion of the monitoring program. The purpose of a written response is to insure that all project team members are aware of the area of concern and that a corrective action plan is in place to prevent reoccurrence. Once the written response is received, the auditor can review the action or actions and close the audit. A written response by electronic mail (email) is an acceptable format for written responses.

Table 4-1. Summary of Audit Observations and Concerns

Site	Description of Concern or Observation	Recommendation
Primary Concerns		
MER	One SO_2 audit response was outside the audit objective of ±15% and analyzer was slow to respond	Perform maintenance on analyzer and determine reason for slow (and low) response
IZT	Three SO_2 audit responses were outside the audit objective of ±15% and analyzer was slow to respond	Perform maintenance on analyzers and determine reason for slow (and low) response
SUR	Two SO_2 audit responses were outside the audit objective of ±15% and analyzer was slow to respond	Perform maintenance on analyzers and determine reason for slow (and low) response
Secondary Concerns		
EAC	Ozone and GPT may be out of specification	Verify that readings were auditor error and that the ozone analyzer is working properly
All Sites	GPT checks are performed using only 2 points.	Three points should be used to assess convertor performance
All Sites	Frequently site departure times were not recorded in the station logbook	Record both arrival and departure time in the station logbook