

TERMS OF REFERENCE

Provide technical support for EEAA newly developed source apportionment monitoring network and chemical speciation analysis operated by EEAA/Cairo University

I. Background

As part of the “Sustainable Development Strategy (SDS): Egypt Vision 2030”,¹the country committed to halving its fine particulate matter (PM₁₀) air pollution by 2030. Significant improvements have been made towards that goal in recent years. In fact, Cairo’s PM₁₀ concentration fell by about 25 percent over the past decade. Despite these improvements, the city’s pollution levels are still several times the WHO recommended concentrations and higher than national guidelines taking as these high levels are taking their toll on the health and quality of life of the population, in particular poor people. Subsequently, the Greater Cairo (GC) Cost of Environmental Degradation (COED) attributed to air pollution is by far the highest in the country, with a mean estimate equivalent to 1.35 percent of national GDP in 2017. Conversely, the GC COED attributed to waste (net of air pollution damages, via the burning of waste) is half the air pollution’s COED and results in a mean estimate equivalent to 0.68 percent of national GDP in 2017 which includes the opportunity losses from composting, recycling, methane capture, etc.^[10] Moreover, recent studies on the COVID-19 show that there is an increased likelihood of contracting the disease with high levels of ambient pollutants.²

Climate change models project Egypt’s mean annual temperature to increase between 2 °C and 3 °C by 2050 and an increase in the duration of long-lasting heatwaves. Hot sandstorms known as khamasin blow millions of tons of grit from the Sahara to the North African coast and increases in local temperatures of up to 20 °C are projected to increase in frequency and intensity. By 2050 the intensity and seasonality of heavy rains, as well as the probability of droughts will increase. Long-lasting heatwaves likely will increase in duration of between 9 to 77 days by 2085. The GC area is vulnerable to all of these, as well as to river and urban flooding, water scarcity and wildfires. The impacts are severe, particularly for public health and agriculture. Climate change will put additional pressures on citizens’ health, in the form of increases in the prevalence and severity of cardiopulmonary conditions through heat and sandstorms, potential increases in vector-borne diseases, through decreased nutrition and food security and reduced water quality.

¹<http://www.cabinet.gov.eg/English/GovernmentStrategy/Pages/Egypt%E2%80%99sVision2030.aspx> and <https://www.greengrowthknowledge.org/sites/default/files/downloads/policy-database/Egypt%20Vision%202030%20%28English%29.pdf>.

² Larsen, Bjorn. 2019. Egypt: Cost of Environmental Degradation: Air and Water Pollution. The World Bank. Washington, D.C.; and Back of the envelop calculations for cost of solid waste environmental degradation performed by the Team.

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Further, it has been demonstrated that extreme heat events are linked to worsening air pollution.³

In response to this situation, the Government of Egypt (GoE) is implementing the Greater Cairo Air Pollution Management and Climate Change Project (hereafter “The Project”) financed by The World Bank. The Project seeks to reduce air and climate emissions from critical sectors and increase resilience to air pollution in Greater Cairo, i.e., Cairo, Giza and Qalubiah Governorates⁴, and is implemented by the Ministry of Environment through its Egyptian Environmental Affairs Agency (EEAA) and its Waste Management Regulatory Authority (WMRA) and in collaboration with other partners. A Project Coordination Unit oversees overall project implementation and ensures that fiduciary requirements are met.

The project aims specifically to reduce emissions that contribute to air pollution concentrations, thus leading to air quality improvements, and to simultaneously mitigate climate change. Air pollutants include PM₁₀ and PM_{2.5}, while climate pollutants include both longer lived greenhouse gases (GHGs) such as CO₂, as well as Short-lived Climate Pollutants (SLCPs) that include black carbon, methane and several short-lived HFCs.

Successful Integrated Climate and Air Quality Management Planning (IC-AQMP) requires a detailed assessment of these emissions in ways that enable decision makers to (i) understand the many sectors that contribute to a city’s air pollution problems, (ii) track the effectiveness of policies and strategies over time to establish an accountability framework for both climate mitigation and AQM planning and (iii) utilize these data to conduct periodic international reporting and to process emissions estimates for dispersion modeling, critical to AQ forecasting.

The Ministry of Environment has developed a roadmap for conducting an updated Source Apportionment Study (SAS) for GC. Implementation of the roadmap and completion of the proposed SAS aims to support Egypt in developing a realistic strategy and plans for managing air pollution in the Greater Cairo region. Ambient air pollution will be managed through reductions of the proportion and concentration of suspended solid particles in the air of the main cities in Greater Cairo, Egypt. This study will utilize a framework to establish an advanced network to monitor the components of suspended solid particles with diameter less than 10 and 2.5 micrometers, respectively. These relatively modern techniques are currently being added to the existing monitoring, analysis and management system for GC, adding capacity in the field of chemical speciation analysis and mathematical modeling using specialized models.

The “Center for Hazard Mitigation, Environmental Studies and Research” at Cairo University was involved in developing the roadmap and will be responsible for implementing the SAS (in its capacity as the body contracted by EEAA to operate and maintain the EEAA national network for monitoring ambient air pollutants). The Ministry of Environment has carried out the monitoring and chemical analysis. The training were conducted as lectures by foreign experts in source apportionment from both the Cyprus Institute and the French National Institute for Industrial Environment and Risks (Ineris).

³Markandya and Chiabai, Valuing Climate Change Impacts on Human Health: Empirical Evidence from the Literature, *Int. J. Environ. Res. Public Health*, 6, 759–86, 2009.

⁴ More details on the Project Components are provided in Annex 1.

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Online lectures were implemented to explain the methods and methodologies that will be used in analyzing the samples through which the study will be conducted, including the following topics:

- Introduction to aerosol impacts, chemical composition, and sources;
- PM Receptor Modeling: Techniques and Applications;
- Other types of source apportionment methodologies and some of their main inputs;
- Overall presentation of Experimental strategy in Cairo;
- Experimental strategy;
- Some general recommendations and site selection criteria to be considered when sitting-up a PM source apportionment study using receptor models;
- Speciation of organic fractions does matter for PM source apportionment;
- Anions-Cations and carbohydrates analysis by IC;
- X-RAY SPECTROMETRY EDXrf and WDXrf for filter analysis;
- EC - OC analysis by thermo-optical method;
- Metals analysis ICP-MS;
- Chemical Profiles Databases;
- Positive Matrix Factorization (PMF) for source identification and apportionment; and
- New tools for improved PMF.

The monitoring equipment for the source apportionment study has already been procured by EEAA for the “Center for Hazard Mitigation, Environmental Studies and Research” to collect the filters required for the chemical analyses, which included 2 Ion Chromatographs (ICs) for ion separation, X-ray analysis via XRF to determine metals and other elements, and OC-EC thermal-optical reflectance for quantitatively determining the fraction of elemental carbon to organic carbon. Training was conducted through lectures on the proper use and maintenance of this equipment to get staff acquainted with the methodologies and scientific methods that is being used in the implementation of the study.

Sample collection stations have been installed in 4 locations in Egypt (Qaha, Tahrir square, El Sheikh Zayed, Masr El Gedida), with each location equipped with 4 devices to monitor each of the PM size fractions with two different filter media, (two samplers for PM₁₀ and two samplers for PM_{2.5} with one sampler for each size fraction collecting on quartz filters and one collecting on Teflon filters). Samples are being collected at those sites every three days, i.e. ten cycles in one month for those samples to be analyzed on the aforementioned chemical analyzers. The collection of samples began on March 21, 2022, in preparation for the chemical analysis of the particulate matter samples accumulated on the collected filters. Approximately 1100 samples have already been collected and stored from the four sites in the GC SA network.

The requested services covered by these terms of reference are **to support implementation of Component # 1 of the Project, on Enhancing the Air Quality Management (AQM) and Response System, implemented by EEAA.** This component aims to support the enhancement of the AQM decision support system in GC through a strengthened AQM infrastructure (monitoring and analytical), capacity building activities, developing emergency response plans and raising public awareness through information dissemination.

II. Objective of the Assignment

The objective of this assignment is to hire a qualified consulting firm, referred to hereafter as “the Consultant” to provide technical support for the newly developed source apportionment (SA) monitoring network and chemical speciation analysis operated by EEAA/Cairo University - including knowledge transfer and capacity building for Egyptian colleagues as appropriate.

III. Scope of Work and Detailed Tasks:

The Consultant is requested to provide technical support for the newly developed source apportionment (SA) monitoring network and chemical speciation analysis operated by EEAA/Cairo University, including knowledge transfer and capacity building for EEAA and “Center for Hazard Mitigation, Environmental Studies and Research”/ Cairo University colleagues as appropriate. This includes aspects of manual sampling, collection, transfer and archival storage, chemical speciation analysis, receptor modeling and reporting over calendar years 2022-2024, inclusive. **EEAA is not looking to replace the current implemented approach being implemented in the source apportionment monitoring network** (Annex # 2 Detailed Implementation Approach). Rather, the team is looking for support to ensure best practices are being utilized and to enhance capacity for the existing approach.

Detailed Tasks:

The Consultant is requested to review and assess the existing capacity & approach of the methods and methodologies that are being used in EEAA Source Apportionment monitoring network.

The Consultant shall carry out a physical training program (**on job training; not online**) for the staff of EEAA, and the “Center for Hazard Mitigation, Environmental Studies and Research” / Cairo University on the methods and methodologies that shall be used in analyzing the samples collected by EEAA Source Apportionment monitoring network (both those which have already been collected and stored as well as those yet to be collected). The training shall include the following:

1. Sample collection, weighing, transfer and storage:
 - The consultant should review the protocols in place and being used for filter media preparation, blank correction, sample collection and transfer and storage at the Cairo University Laboratory.
 - The consultant should review sampler operation and maintenance to ensure that the manual samplers will be fit for purpose over the lifetime of the network.
2. Using analytical instruments, and handling of data:
 - Using Ion chromatography instrument for --- carbohydrates, especially handling of data from the instrument;
 - Using Ion chromatography instrument for --- anions and cations; and
 - Using XRF instrument, and how to modify the measurement method to be suitable for the measurement conditions in Egypt.
 - Using EC-OC instrument, and how to modify the measurement method to be suitable for the measurement conditions in Egypt.

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3. PMF Modeling for Air Pollutants:

The Consultant shall provide introduction to PMF Modeling for Air Pollutants. This introduction should provide an overview of the principles and techniques of PMF modeling for air pollutants. Topics to be covered should include the fundamentals of PMF modeling, the types of pollutants that can be modeled, and the advantages and limitations of this approach.

4. Data Collection, Validation and Preparation:

The training to be conducted by the Consultant on the PMF Module has to cover the steps involved in collecting and preparing data for PMF modeling. Topics to be covered should include data sources, data quality control and quality assurance, data cleaning/validation, and data transformation.

5. Model Development:

The training to be conducted by the Consultant on the PMF Module should cover the steps involved in developing a PMF model for air pollutants from the four-site network. Topics to be covered should include model selection, parameter estimation, model validation, and sensitivity analysis.

6. Application of PMF Models:

The training to be conducted by the Consultant on the PMF Module should cover the application of PMF models to real-world problems related to air pollution in GC. Topics to be covered should include case studies from Egypt's results, as well as best practices for using PMF models in policymaking and decision-making processes.

7. Advanced Topics in PMF Modeling:

The training to be conducted by the Consultant on the PMF Module should cover advanced topics related to PMF modeling for air pollutants, such as source apportionment techniques and uncertainty analysis methods.

IV. Administrative and Reporting Arrangements

The Consultant will work under the supervision of and report to the Head of the Environmental Quality Department, in his capacity as the Head of the Technical Implementation Unit of Component 1 of the Project, and/or his designee and with the Lead Advisor of the Component. Contract management and other administrative responsibilities are overseen by the Project Coordinator of the Greater Cairo Air Pollution Management and Climate Change Project, or his designee.

The consultant will closely work with EEAA staff members of the TIU, and will collaborate with Cairo University.

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VI. Duration of the Assignment

The Consultant will work to complete deliverables between **1st August 2023** and **31st January 2025** within **18 months** of the start of contract. This work will require reporting to the EEAA as outlined above.

VII. Deliverables

Serial No.	Deliverable	Time from Contract Signature
1	Inception Report & Roadmap Report & Training plan	1 month
2	Conduct on job training program for the staff of EEAA, and the “Center for Hazard Mitigation, Environmental Studies and Research” / Cairo University on the methods and methodologies that are used in sites selection, samples collection, analyzing the samples collected by EEAA newly developed Source Apportionment monitoring network. This includes aspects of manual sampling, collection, transfer and storage, chemical speciation analysis for the different instruments, receptor modeling, processing, and reporting.	4 months
3	End of year 2023 Progress Report.	5 months
4	Conduct 4 on-site missions to follow up on the progress of the source apportionment monitoring network (one mission every calendar quarter).	5 - 17 months
5	Final Report.	18 months

IX. The Consultant Qualifications and Experience

- Experience in air quality management planning.
- Experience in developing source apportionment monitoring networks, chemical speciation analysis, and receptor modeling.
- Experience in manual sampling, data collection, transfer and storage.
- Experience in using analytical instruments (Ion chromatography, XRF), handling of data from the instruments, and modifying the measurement methods to be suitable for the measurement conditions in Egypt.
- Experience in PMF Modeling for air pollutants (principles, techniques, & steps involved in developing a PMF model for air pollutants);
- Experience in collecting and preparing data for PMF modeling for air pollutants, including data quality control, data cleaning, and data transformation.
- Experience in using the application of PMF models to real-world problems related to air pollution.
- Experience in advanced topics related to PMF modeling for air pollutants, such as source apportionment techniques and uncertainty analysis methods.
- Experience in using PMF models in policymaking and decision-making processes.

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- Experience in chemical analysis, and establishing ongoing reporting mechanisms.
- Experience in international reporting.
- Experience in establishing ongoing data management and reporting mechanisms.
- Broad access to both academic and private sector expertise that can contribute knowledge to the Egyptian agencies, institutions and personnel.
- Experience in capacity building in chemical analysis, modeling and international reporting, and in undertaking complex data analysis and environmental assessments in low- and middle-income countries.

The consultant staff will be available for meetings and appointments per the schedule of the EEAA. The consultant will be expected to present results and provide Progress Report to EEAA every 3 months during the contract period.

Annex # 1

Greater Cairo Air Pollution Management and Climate Change Project

The Government of Egypt (GoE) is currently implementing **Greater Cairo Air Pollution Management and Climate Change Project** (the Project) financed by The World Bank. The Project seeks to reduce air and climate emissions from critical sectors and increase resilience to air pollution in GC, i.e., Cairo, Giza and Qalyubia Governorates and is being implemented with Ministry of Environment (MoE) in close collaboration with Ministry of Local Development (MoLD), Qalyubia Governorate, Cairo Transport Authority (CTA) and other stakeholder agencies. The Project focuses on two main sources of air pollution: solid waste management and vehicle emissions in GC region and includes the following five main components:

Component 1: Enhancing the Air Quality Management (AQM) and Response System: This component aims to support the enhancement of the AQM decision support system in GC through a strengthened AQM infrastructure (monitoring and analytical), capacity building activities, developing emergency response plans and raising public awareness through information dissemination.

Component 2: Support the Operationalization of Solid Waste Management (SWM) Master Plans in GC: This component aims to support operationalization of Governorate SWM master plans, which lay down the full range of necessary actions and investments needed for each governorate to improve SWM services in accordance with the specificity of each Governorate. In view of the complexity and magnitude of SWM system in GC, the Project follows a phased and gradual approach to achieve tangible results on the ground. This approach involves providing technical support at the central level to the Waste Management Regulatory Authority (WMRA) and the MoLD and specific investments, technical, financial and project development support to SWM actions at the local level to the Qalyubia Governorate.

Component 3: Vehicle Emission Reduction: This component aims to support activities aimed at reducing vehicle emissions from public transport sector. This shall be achieved through procurement of about 100 electric buses and the infrastructure required to operate and maintain these buses. The component will also support the CTA in acquiring the needed knowledge and experience in operating and scaling up electric bus fleet in Cairo. The Project will also upgrade facilities at CTA, including retrofitting existing bus depots with electric charging stations, power supply and related safety equipment; training CTA staff such as bus drivers and mechanics on operating and maintaining the new e-equipment.

Component 4: Communication and Stakeholders Engagement: This component aims at ensuring that all stakeholders, in an inclusive manner, are actively involved in the design, implementation and monitoring of all Project activities and the Project is implemented following a full consultative participatory approach that is meant to build a constructive relationship between the stakeholders and the GoE. This component is complementary to the comprehensive

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Stakeholders Engagement Plan (SEP) developed as part of the environmental and social risk management.

Component 5: Project Management and Monitoring and Evaluation (M&E): This component will support the establishment of Project Coordination Unit (PCU) at MoE and four Technical Implementation Units (TIU) for each of the first four components.

Component 6: Enhanced E-Waste and HCW management for Reduction of uPOPs: It is an additional finance (AF) to the parent project, this new activity focuses on reduction of unintended persistent organic pollutants (uPOPs) aligns with the “GEF Project Design and Review Considerations in Response to the COVID-19 Crisis and the Mitigation of Future Pandemics”.

Annex # 2**Air samplers**

No	Instrument	Model	Principles of Operation
1	ARA Sampler	N-FRM	The N-FRM Sampler is specifically designed to meet the US-EPA operational specifications for PM₁₀ and PM_{2.5} air sampling. To meet the EPA specifications, the N-FRM Sampler is designed to operate at 16.7 LPM and collect 24-hour samples to compare to EPA National Ambient Air Quality Standards. The ARA N-FRM Sampler is a microprocessor-controlled portable air sampler, which can be operated manually or programmed to collect scheduled samples. As specified by the EPA, all critical air sampling parameters are continuously monitored and logged as time indexed 5-min averages to validate the sample. These parameters include: flow rate, temperature, barometric pressure, and accumulated volume. Other sampler related performance parameters are also logged. If the N-FRM Sampler is equipped with the Real-Time Particulate (RTP) Profiler and meteorological sensors, then PM₁₀, PM_{2.5}, wind speed, and wind direction are also included in the data record. The N-FRM sampler can be easily deployed. It can be mounted on a variety of structures using our universal mounting bracket that can be screwed, clamped, or attached to utility poles, trees, fence posts, etc. Another option is to use a freestanding tripod. The N-FRM Sampler is equipped to operate from either AC or DC power sources. In the DC mode, the sampler operates from an internal battery pack. A charged battery pack is capable of operating the sampler for about 30-40 hours. This robust capacity allows the sampler to be used in cold weather and high altitude applications. A charger is supplied so the batteries can be re-charged in approximately one hour.

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Chemical Analysis Instruments

No	Instrument	Model	Methodology
1	Rigaku WD-XRF	supermini 200	XRF for metal elements requires Teflon filters, and the measurements are performed after finishing the gravimetric analysis on the same Teflon filter as follows: - For storage at cold conditions (at least below 5°C), ice boxes for the Teflon filters is used. Element to be determined are (Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Se, Br, Rb, Sr, Sn, Sb, Ba, Pb). - Certified control filters are to be used for quality control. - The filter is removed from the box and placed in the sample holder of the instrument using forceps. - Holder containing sample filter is covered with the Mylar film. - Eight samples can be measured in the same run. - Each sample measurement consumes about 25 minutes. - After finishing measurement, instrument software is used to manipulate data, and get the final data in the form of $\mu\text{g}/\text{m}^3$. - Samples are measured again, so two reading is available for each sample. - Data are collected in the excel sheet.
2	Sunset® total carbon analyzer	Lab OC-EC Aerosol Analyzer	- Quartz filters shall be pre-heated at 500 degrees Celsius during 24 hours, and then stored in very clean conditions, to minimize contaminations; square part of the filter of length 1.5 cm is punched and used for analysis in the analyzer. - For calibration and quality control, blank filter is analyzed to check any laboratory contamination; referent filter from air sample with 10 punches analyzed (criteria 10%) to check the analytical repeatability; filter spiked with organic solution (glucose, criteria 10%) - To check the calibration; calibration of thermocouple measuring temperature in the oven each time a maintenance is achieved on the oven. - No existing EC or OC standard reference material, but automatically calibration by injection of CH_4 at the end of each sample analysis; Linearity from spiked filter (glucose or sucrose) every 6 months (and after replacing CH_4-containing gas cylinder). - Each filter is measured twice where each sample consumes about 40 minutes; the data is handled using instrument software to get both elemental carbon and

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			organic carbon, and sum gives total carbon in $\mu\text{g}/\text{m}^3$ which is collected in the excel sheet.
3	930 Compact IC Flex for carbohydrates –940 professional IC Vario for cations and anions.	Metrohm®	C carbohydrates, anions and cations analyses are performed for a second punch from the quartz filter as follows: - Standard solutions 5 points (at Least) are prepared: 0.01 -10mg/L, equivalent to 0.2 -200 μg are prepared. Work from 2 calibrations, Low calibration (LOQ1 mg/L) and High calibration (1 mg/L 10 mg/L), for each compound, LOQ is typically of about 10 $\mu\text{g}/\text{L}$ or 0.2 μg. Blank filter is analyzed to check any laboratory contamination. - Injection of a standard every 10 samples: (criteria 15%) to check the analytical drift; injection of an independent standard (criteria 10%) to check the calibration; injection of the first standard at the end of the analytical run (criteria 30%) to check the LOQ. - Punch of the filter of area ($1.5 \times 1 \text{ cm}^2$) is used; the species to be analyzed are extracted from the filter punch using ultrapure distilled water; filter punch is placed in vial with 20 mL ultrapure distilled water, followed by sonication (using FB15067 Fisher brand® sonicator) for 10 minutes and shaking (Fisher brand® shaker) for one hour. - The supernatant liquid is filter using syringe filter, and be analyzed for carbohydrates at first, followed by anions and cations analysis. Analyses are performed twice for each sample. - The sample consumes about 50 minutes for both carbohydrates with anions and cations; data is handled using instruments software, and data is collected in the excel sheet.
4	Balance	AND BM-5	- Before sampling, For Teflon filters, two consecutive weighing (m_{b1} and m_{b2}) will be carried out with 12 h time interval and an average filter mass ($m_{b, \text{mean}}$); The difference between (m_{b1} and m_{b2}) will be $< 40 \mu\text{g}$. Set a sampling timeframe corresponding to 8:00 AM to 8:00 AM (24 h). Visit site to collect filter, for storage at cold conditions (at least below 5°C using two ice boxes for Teflon filters, just after the sampling is achieved. - After sampling, at least two weighing (m_s, 1 and m_s, 2) should be carried out with 24-h time interval. The difference between the last two results shall be lower than $60 \mu\text{g}$. If this condition is not eventually fulfilled, the result is declared invalid. The sampled filter mass is the average of the last two consecutive weighing (m_c, mean).

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			- The final PM mass collected on the filter is the difference between mms, mean and mc, mean Certified standard masses and control filters are to be used for quality control. - Before weighing, the filters are stabilized for at least 48 hours under controlled conditions (temperature and relative humidity ranges of 19-21°C and 45-50%, respectively).
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Positive matrix factorization (PMF):

It is a recent development in the class of data analysis techniques called factor analysis, in which the fundamental problem is to resolve the identities and contributions of components in an unknown mixture. PMF has been used extensively for source apportionment of ambient particulate matter (PM), where the goal is to resolve the mixture of sources that contributes to PM samples.

PMF is especially applicable to working with environmental data because it:

- (1) Incorporates the variable uncertainties often associated with measurements of environmental samples and
- (2) Forces all of the values in the solution profiles and contributions to be nonnegative, which is more realistic than solutions from previously used methods like principal components analysis.

Modern-day sampling networks provide time-resolved speciated ambient aerosol data that include trace and crustal elements, ions, organic (OC) and elemental carbon (EC) fractions, and PM concentrations. PMF has been used to identify and apportion sources of airborne PM by analyzing these species (or a subset) measured at many locations around Cairo.

Profiles and contributions of PM from primary sources, such as motor vehicles, residential and industrial fuel combustion, biomass burning, soil dust, and sea salt are typically identified by PMF analyses in these studies. Secondary sources, such as atmospheric oxidation of sulfate and nitrate and heterogeneous gas-to-particle conversion reactions on soil dust surfaces, have also been identified with PMF.

Despite the extensive use of PMF, there exists considerable variation in the procedures followed and decisions made to apportion sources of ambient PM using PMF.

The modeling procedures may be divided into three broad steps:

- (1) Preparing data to be modeled,
- (2) Processing the data with PMF to develop a feasible and robust solution, and
- (3) Interpreting the solution. Specific decisions, such as the creation of data uncertainties, selection of the best number of factors, and treatment of outliers, need to be made when carrying out these steps. In our work for PMEHI we will determine which steps are common and which are unique for Cairo.