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A research plan for a new environmental chamber facility

by

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Mexico City's air pollution is a persistent and pervasive environmental problem that has imposed health and economic costs on society. With Mexico's expenditures on controls calculated in several millions of pesos per year and slow progress toward compliance with air quality standards, a critical need exits for better and more effective abatement strategies. With the current Federal Environmental Policy on fossil fuel burning for power utilities and industrial processes shifting from heavy fuel oils to low sulfur natural gas, it becomes important to characterize industrial emissions as well as residential emissions that use gaseous fuels for establishing their impact on the Mexican airshed. Concurrently, it is recognized that an efficient strategy to abate air pollution in Mexico City consists of improving the properties of Mexican liquid fuels for transportation. Although liquid hydrocarbons have been substantially improved to comply with environmental regulations not much has been done to evaluate exhaust gas emissions and their role in ozone and aerosol formation.

The need to address the above-interrelated topics demands great efforts in reducing air pollution. Common obstacles in this pursuit include insufficient understanding of the relationship among the underlying scientific, economic, and social issues, and also in addressing the problem with limited availability of resources, and infrastructure. Although addressing all these issues collectively is out of the scope of the present investigation, much can be accomplished by devising more prominent scientific methodologies and experimental techniques that can shed new light in mitigating and controlling air pollution in Mexico's populated cities. An integrated assessment will provide the opportunity to understand the air pollution problem and its coupling to regional and global impacts. Mexican researchers at the IMP are initiating multidisciplinary work in which the city's environmental problems are being addressed. The major objective of this investigation is aim at acquiring scientific knowledge to address the still prevalent high concentrations of fine particles and ozone formation in the Mexico City Metropolitan Area (MCMA).

A two-step approach is devised to carry out the objectives of this investigation. The first task relies on experimentation to gather enough information that can be used later on for tuning parameters and refining chemical reaction mechanisms in ozone formation modules embedded in advanced urban and regional models for regulatory purposes. Modeling of important episodes and historic events will be a key element in evaluating the impact of emission sources into the air. During the experimentation phase smog chambers will be used for determining gas precursor contribution from both gaseous fuels and tail pipe emissions from combusted liquid hydrocarbon fuels on ozone formation. This phase will characterize Volatile Organic Compound (VOC's) reactivates including exhaust gas and evaporative liquid fuel as well. The adopted methodology will be based on reactivity indexes to estimate VOC's reactivity in controlled atmospheres inside radiated environmental chambers. The incremental reactivities of a series of representative VOC's are expected to differ from those measured by Carter in previous studies since the VOC to NOx ratio, VOC's speciation and radiation fluxes typical of the Mexican airshed vary considerably from that of northern latitudes. In this line of work computer modeling of environmental chamber measurements of incremental reactivity of VOC will be pursued in order to evaluate detailed atmospheric photochemical mechanisms for developing ozone reactivity scales for VOC's.

The present experiments will complement studies under high NOx maximum reactivity conditions and enable our research group to gain sufficient knowledge in this area of expertise. The scope of the present work is not only centered on the design and characterization of smog chambers but also to adopt existing technologies to carry out the activities herewith described and to study heterogeneous processes related to chamber wall effects.

Another branch of research that the project contemplates is aerosols. Fine particle formation within the MCMA when strong photochemical activity takes place severely affects not only the urban airshed but also air quality of downwind rural areas. In the Mexico City basin airborne particles contribute significantly to light scattering and absorption and hence, visibility reduction, which is related to both light-particle interaction and gas-to-particle processes, is drastically hinder by the intense human activity of the region. The complex heterogeneous chemical reactions between gaseous pollutants and suspended particles that occur during aerosol formation are not well understood. Further information is necessary to explain aerosol formation as favored through photochemical reaction of gases and vapors in semiarid atmospheres. Although the mechanisms responsible for inorganic aerosol formation seem to be well characterized, very little is known on the chemistry of organic aerosols. Mexican authorities have recognized the urgency to address issues relevant to visibility reduction and aerosol formation in order to improve Mexico's air quality. To resolve such problems a better understanding of the complex heterogeneous atmospheric chemistry is required. It is therefore of paramount interest for researchers at IMP to initiate chamber studies of aerosol formation and to actively participate with other research groups in related projects. This collaborative effort will fortify common areas of research and will enable us to provide the answers that are needed to mitigate pollution in megacities.

A key element distinguishing this project from other air pollution research is its multidisciplinary nature and the myriad areas of research that it encompasses. Air quality modeling is the focus of the second phase of this investigation. Advanced air quality models will be used to simulate photochemisty along with transport and formation of aerosols. Models will be developed to study the formation of inorganic and organic aerosols. Chemical mechanism development and evaluation for low vapor organic compounds that are formed in photochemical atmospheres are considered as a fundamental part of the investigation. Gas-particle equilibrium models for VOC's are fundamental to investigate the gas to particle pathways and particle growth that characterize aerosol formation in the basin's atmosphere. There is also a great need to study VOC accumulation on soot particles, as the number of sources that emit soot is considerably large in the region. To determine the origin, relative contribution and distribution of particles and volatile organic compounds receptor models will be used. Receptor models will aid in characterizing the VOC sources while providing a tool to evaluate the effectiveness of pollution control strategies.

The impact of aerosols on the radiation budget will be evaluated as a first estimate on regional climate change. Linking the local and regional air quality issues that are most important to local decision-makers to factors affecting global change, the proposed assessment offers a new opportunity to advance effective polices on both fronts.

With the scientific platform on which this project rests air quality models will be successfully used to estimate future scenarios that may arise as a result of a number of modifications or implementations on a regional scale. For instance a shift form residual fuel oils to natural gas applied on the industrial sector. Improved liquid fuels introduced into the market for transportation. Addition or removal of various types of emission sources in the area as well as the effect of adding air pollution control systems for power generation units, or other commercial combustion applications. The project contemplates the simulation of different scenarios to evaluate the ambient impact of aerosol when using reformulated fuels according to a refinery system upgrade. The complementary tasks to support the project's activities in the second phase, such as reactivity indexes and the development of explicit reaction mechanisms will derive from a new-planed experimental facility designed for high-volume environmental chambers.