Toxicological Evaluation of $PM_{2.5}$ and PM_{10} in the City of Mexicali and its Correlation with Soil Content

A study to evaluate and direct control measures

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Executive Summary

Located on the border between the Mexican state of Baja California and the U.S. state of California, the city Mexicali is plagued with poor air quality. Not only is the city located in an unfavorable climatic region – in the middle of a desert -, but it also suffers from unsustainable economic growth along the border region, which results in the location of highly polluting industries in its vicinities and the influx of old polluting vehicles from the United States. These many factors combine to result in some of the highest levels of particulate matter in North America. Due to its unique circumstances and prior evidence of the toxicological characteristics of its soil, the city of Mexicali was chosen for an in-depth study of its particulate matter pollution problem. The primary objectives of this study were to characterize the composition and toxicity of Mexicali's particulate matter and to analyze options for its control.

Fine (particles with aerodynamic diameter of less than 2.5 μm, $PM_{2.5}$) and inhalable particulate matter (particles with aerodynamic diameter of less than 10 μm, PM_{10}) were collected for one year (October, 2005 – September, 2006) from two sites in Mexicali: a semirural site and an urban site. Particulate matter of both size fractions and from both sampling sites was made up of a complex mixture of 16 elements, which were generally grouped into elements of geological (soil) origin,

which were abundant in samples from both sites, and elements of anthropogenic sources, which were prominent in samples from the more urban site. PM_{10} of soil origin also contained sulfur and magnesium, indicating possible contamination from anthropogenic sources.

Biological tests identified that PM from the two main sources had differential toxicological impacts, with particles rich in elements of anthropologic origin having greater pro-inflammatory potential, while PM rich in elements of geologic origin had greater cytotoxic potential. These results corroborate the assumption that PM of different composition can lead to varying toxicological patterns and possibly different health outcomes. In terms of human health, these results indicate that PM of geological origin are more closely associated with biologic mechanisms that can result in severe health consequences like pulmonary fibrosis, growth retardation and even cancer. In contrast, PM of anthropogenic origin produced more inflammation which can have serious pulmonary and cardiovascular impacts, such as lung and systemic cardiovascular diseases. These results were generally true for size fraction as well, with fine PM having higher pro-inflammatory potential and PM_{10} being more cytotoxic and pro-inflammatory depending on its origin.

The toxicological component of this study indicates that air quality management efforts should aim to reduce both the fine and coarse fraction of particulate matter as well as particles from both anthropogenic and geological origin. These conclusions are reinforced with the results from the analysis of control measures. All measures analyzed, which included controls of particles from mobile, biogenic and geologic origin, would result in significant benefits for the health of people living in Mexicali. In monetary terms, each measure would result in annual health benefits between around $1.5 and $2 million U.S. dollars. The costs and feasibility of each measure, however, would need to be analyzed to determine their net benefits and to be able to prioritize the controls.

The pavement of dirt roads was found to be the most beneficial measure in terms of public health outcomes. This finding was robust to assumptions about the

differential impacts of fine and coarse PM fractions. With the additional toxicological evidence that particles rich in elements of geologic origin are uniquely toxic, this measure is found to be especially important. The control of agricultural burning also resulted in significant health benefits in terms of its control of both $PM_{2.5}$ and PM_{10}. Finally, the renewal of the diesel bus fleet is most beneficial when incorporating advanced emissions control technologies (particle traps) and clean fuels. Replacing the fleet with newer, but not state-of-the-art vehicles has the least impact of the four control measures analyzed here. Certain key control measures were not analyzed, such as measures to improve the technologies of the private automobile fleet and to stabilize surfaces in empty lots to reduce the emission of wind-blown dust. Insufficient local information, however, was available to analyze such measures for the purposes of this study.

This study confirms the growing evidence that size, composition and origin of particulate matter interact in a complex manner to determine particle's impact on human health. Due to the complex interaction between these factors, it is beneficial to understand the characteristics of local particulate matter and incorporate this information in the identification of control measures. The unique toxicological potential of larger particles of geologic origin was confirmed in this study and therefore its control should be addressed simultaneously and separately from fine PM of anthropogenic origin.