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Health Impact of Blending Ethanol into Gasoline in 5 Global Cities

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Study Overview:

We assessed the health impacts from blending ethanol at levels of ten and twenty percent by volume (E10, E20) into gasoline in five mega cities around the world: Beijing, Delhi, Seoul, Tokyo, and Mexico City. The unique feature of the study is that it explores the comprehensive environmental linkages from fuel formulation through health impact. It takes into account: a) the regionally specific fuel blending requirements to meet local fuel specification, b) the calculated tailpipe emissions reductions in the local vehicle fleet and the local vehicle technology, c) the concentration reductions in the local atmosphere from the reduced tailpipe emissions, d) the localized health impact and treatment cost.

The total mass of emissions reductions from several classes of pollutants were documented in the study including volatile organic compounds (VOC), nitrogen oxides (NOx), particulate matter (PM) and carbon monoxide. However, the health assessment part of the study focused on air toxins which are generally a subset of VOC and PM (also dioxins and metals).

Compared to the 100 plus years of gasoline utilization the addition of larger ethanol volumes is a relatively recent development which prompted health impact studies in the past to focus mostly on ensuring that ethanol as an additive does not deteriorate the blends' emissions profiles. The emerging literature goes beyond this approach and documents the direct causality of air toxins reductions with ethanol blends as follows:

> Gasoline contains a large amount of aromatic hydrocarbons that are added to gasoline because they have relatively high octane values and therefore serve as anti-knock agents in vehicle engines. Some aromatics are toxic compounds. Ethanol also has a high octane value and contains no aromatic compounds. It therefore substitutes and dilutes aromatics in gasoline. Moreover, ethanol also alters the distillation curve resulting in an adjustment of the distillation properties of the fuel with, for example a higher volume fraction of the fuel distilled at 200 degrees Fahrenheit. This effect further reduces the formation of toxic emissions in a vehicle.

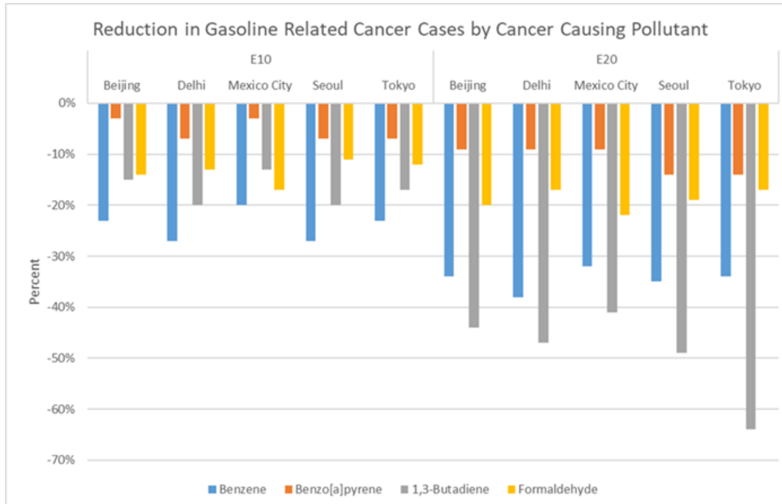
In fact, the recent Fuels Trends Report by the US Environmental Protection Agency discloses the connection between ethanol and aromatics in gasoline and states: "Ethanol's high octane value has also allowed refiners to significantly reduce the aromatic content of the gasoline, a trend borne out in the data". The toxic compounds from the fuel as well as additional compounds formed during the combustion process are either emitted through exhaust, crankcase and evaporative processes.

Some of the toxic pollutants specifically affected by ethanol blends are aromatics (benzene, polycyclic aromatic hydrocarbons also known as PAHs), alkanes (such as butadiene) and aldehydes (e.g. formaldehyde, acetaldehyde). Due to their carcinogenity the US EPA and the California Office of Environmental Health Hazard Assessment (OEHHA) have established inhalation unit risk factors (IUR) which is a standard metric for estimating excess lifetime cancer risk from inhalation exposure. The IUR factor has units of risk per 1 ug/m3 inhalation exposure.

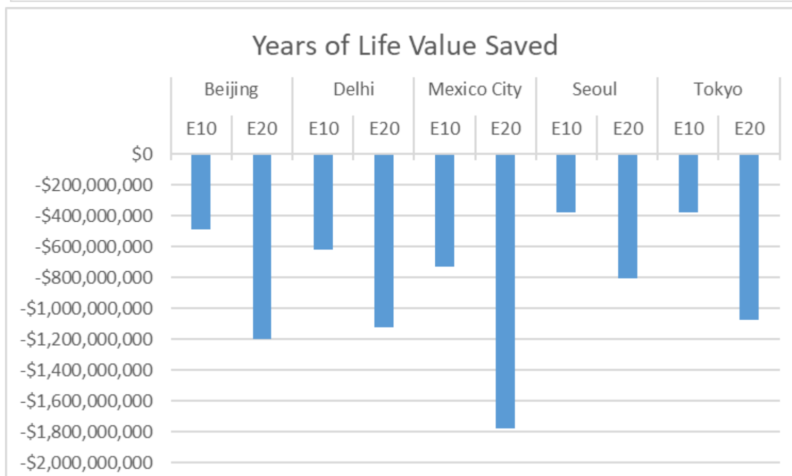
By assessing which fuel formulation compounds are affected by ethanol blending and focusing on speciated emissions for which definitive IUR factors have been established the present study conclusively documents the positive health effects of ethanol. However, there are additional health benefits that have not been quantified including asthma reductions from the reduction of PAHs with ethanol as well as ozone reductions particularly in cities where VOC is a precurser to ozone formation. While these effects are likely significant in magnitude and documented in recent publications their quantification requires sophisticated atmospheric dispersion models and emissions speciations from ethanol blends in the local vehicle fleet.

<u>Study Results:</u>

The introduction of ethanol fuels was estimated to yield a net reduction of approximately 200-300 cancers per city from the reduction in the ambient air concentration of selected toxins. For example, the graph to the right indicates that over 20% of gasoline benzene related cancer cases can be avoided in every studied city from the introduction of E10.



Avoiding these cancers will save several thousand years of potential life lost in each city and an additional tens of millions of dollars of direct healthcare costs for cancer treatment. The impact of cancer, however, is much greater than these metrics, as cancer adversely impacts the quality of life, can lead to loss of income, and devastates families. For example, in the US, a person-year of life lost has been valued at $150,000 which leads our assessment to show several hundred million dollars of savings from ethanol blends (see graph).



For context, other regulatory actions have been taken to prevent numbers of cancers that seem modest relative to the total burden of disease. For example, in the reduction of the Permissible Exposure Limit for 1,3-butadiene in the United States to 1 ppm was estimated by the Occupational Safety and Health Administration to avoid 59 cancers among approximately 9000 exposed workers over a working lifetime of 45 years, or 1.3 cancers per year. Costs to employers to comply with the new 1,3-butadiene standard was estimated to be $2.9 million in 1996 dollars annually, or approximately $2.3 million per cancer avoided per year. Similarly, the reduction in the Permissible Exposure Limit for benzene from 10 ppm to 1 ppm was estimated by the Occupational Safety and Health Administration to avoid 326 deaths from leukemia and other lymphohematopoietic cancers over 45 years, or 7.2 cancers per year; a reduction of similar magnitude to the presented ethanol blended gasoline efforts.

The health benefit of transitioning to ethanol fuels in these five cities is quantifiable and significant relative to the total burden of disease within the context that gasoline vehicle exhaust is one of many contributors to air pollution. The results of the study suggest that transition to ethanol fuels will benefit public health. The study also shows that comparative emissions savings under reasonable electric vehicle adoption scenarios will likely not be achieved for the next 10 years.