Natural Background for Wichita Mountains of Oklahoma

The Clean Air Act declares a goal to remedy any visibility impairments in the Wichita Mountains of Comanche County, Oklahoma and all other mandatory Class I federal areas that result from manmade air pollution. Understanding this goal necessitates a quantification of natural and anthropogenic sources of visible light extinction. The U.S. Environmental Protection Agency (EPA) promulgated a federal regional haze rule that requires Oklahoma to submit an implementation plan for reasonable progress to improve visibility in the Wichita Mountains on the worst quintile of days along a logarithmic haze index in regulatory units called deciviews.

Guidance for estimating natural visibility conditions from EPA relies upon a chapter that John C. Trijonis wrote in the 1990 National Acid Precipitation Assessment Program report. He considered an Eastern zone extending one tier of states west of the Mississippi River and a Western zone comprising arid deserts and adjacent mountains. For six components of aerosol responsible for light extinction, Trijonis provided annual-mean natural concentrations averaged over each zone with broad error factors. The default approach for estimating natural conditions simply assigns the regional mean for the Western zone to the Wichita Mountains. EPA also welcomes proposed alternatives based on available monitoring information and appropriate data analysis techniques and invites a choice between Western and Eastern zones.

The default estimates for the Western and Eastern zones of Trijonis differ only in sulfur and organic carbon aerosols. Sulfur aerosols alone contribute a majority of light extinction, especially on days among the worst quintile. Prevailing southerly anticyclonic flow brings these aerosols mostly from elevated point sources in Texas and the Eastern zone to the Wichita Mountains. This flow also carries any natural sulfur aerosols from those Eastern source regions. Local sulfur sources include gypsum and other sulfurous minerals in the soils, sulfur springs, and petroleum seeps. The Wichita Mountains fit well within the Eastern airshed.

Nitrate particulate haze occurs primarily on cold northerly winter flow from rather desolate and rural Great Plains and on return flow from Texas. Nitrates cause a majority of visible light extinction on many winter days among the worst quintile. Outside the hibernal season, nitrate emissions undergo different photochemical reactions. Central Regional Air Planning Association (CENRAP) modeling widely overestimates nitrate particulate and places considerable culpability on mobile and poorly inventoried area sources. Animal wastes may contribute significantly to natural ammonium nitrate aerosols.

Only combustion releases elemental carbon particulate, so wildfires provide the only significant natural source. Elemental carbon never comprises more than one-tenth of light extinction observed in the Wichita Mountains. Modeling implicates on-road, non-road mobile, and area sources. The incidence of prairie fires increased markedly since 1990 but still does not approach their frequency under Native American management since the last glacial. Some endangered species on the Wichita Mountains Wildlife Refuge now depend on fires for necessary habitat.

Plant growth, animals, fires naturally emit much organic carbon particulate. The Wichita Mountains boast a normal precipitation of 34.19 inches per year, only slightly less than most Eastern sites. Satellite imagery indicates high plant productivity across the American South as far west as the refuge. Trijonis expected more natural organic carbon particulate in the South than in the Northeast or Midwest. Many biogenic models increase vegetative organic emissions with heat stress common here. CENRAP modeling, however, captured only a minority of organic carbon observed in the Wichita Mountains. This poor model performance reflects poorly understood organic emissions and chemistry and signals a need for a well-funded field study to determine the identity and chemistry of observed organic particulates and to identify their natural or anthropogenic sources and sinks. The modeling does not implicate potentially significant petroleum and natural gas sources. Without any field-study results, Oklahoma cannot identify significant controllable anthropogenic sources nor refute the classification of the overwhelming majority of these particulates as natural or related to fires.

Back trajectories suggest a strong Saharan contribution to fine-soil particulate matter. Coarse matter overwhelmingly dominates North Plains, West Texas, and Southwestern dust and sand storms; they bring only small fine soil concentrations. Any coarse Saharan dust generally deposits gravitationally during the two- to three-week transatlantic journey; only some fine soils reach Oklahoma. CENRAP grossly over-modeled fine soil particulate.

CENRAP models accounted for only half of coarse particulate observed in the Wichita Mountains and attributed it overwhelmingly to natural or poorly inventoried area sources. Occasional turbulent gales sweeping across the semi-barren dry High Plains and Southwestern deserts raise coarse particulate. Gobi Desert dust and sand also sometimes land in Oklahoma. Oklahoma considers these events as natural as denuded spots amid patchy xeric vegetation. Archaeological excavations document shifting medieval Great Plains sand dunes. Modern farmers and ranchers painfully learned soil conservation from the Dust Bowl. Plants and animals also can emit significant coarse particulate, but we lack any confidence in our ability to model biogenic or other organic particulates of any size.

High upwind biological productivity, frequent winds from the Eastern airshed, and relatively high precipitation support classification of the Wichita Mountains in the Eastern zone rather than in the Western zone. Natural visibility conditions, however, change constantly with the climate. The Wichita Mountains lie astride a sharp, ever-shifting gradient in precipitation between swampy humid forests and partially barren short grass prairies and deserts. The present climate eventually will turn markedly drier, increasing the influence of fires and dust storms while decreasing non-fire organic aerosol. Multi-decadal switches may modulate Saharan dust. Natural concentrations of particulate responsible for visible light extinction consequently vary among quinquennia.

Clean Air Interstate Rule, gasoline improvements, and other already enacted emissions reductions should contribute to the improvement of visibility in the Wichita Mountains. CENRAP modeled an improvement from 23.8 deciviews in 2004 to 21.5 deciviews by 2018. We can extrapolate this rate of improvement until visibility at the Wichita Mountains ultimately improves to meet natural conditions. If we consider all fine soils, coarse matter, and organic particulate as natural and reduce sulfate and nitrate aerosols to a constant low threshold consistent with Eastern natural conditions, then this proposed extrapolation reaches "natural" conditions in the Wichita Mountains circa 2058.

Although EPA defaults consider the Wichita Mountains of Oklahoma a Western site, its present climatology strongly suggests that its natural visibility conditions better match those of the Eastern states. The Western and Eastern regional mean natural-conditions estimates of Trijonis differ only in sulfurous and organic aerosol concentrations. Prevailing southerly anticyclonic flow brings these particulates from source regions immediately and distantly upwind. Rainfall in the Wichita Mountains presently suffices for especially high plant productivity amid significant heat stress, the recipe for especially high biogenic emissions. Smoke from prairie fires contributes further to natural organic carbon concentrations and contains elemental carbon particulates. The Wichita Mountains receive seasonal Saharan fine soil dust and occasional dust storms from the Southwestern deserts and windswept High Plains. The location of the Wichita Mountains gives the refuge a dramatically and constantly changing climate with considerable inter-quinquennial variability in natural aerosol component concentrations. Presently available modeling does not capture most fine organic and coarse particulate and attributes rather little of either component to anthropogenic sources. We therefore lack a necessary understanding of the organic and coarse particulate in the Wichita Mountains, and absent a well-funded field study, we cannot identify significant anthropogenic sources. In addition to using the default glide-slope of EPA to help assess reasonable progress, the Oklahoma Department of Environmental Quality plans to present a weight of evidence determination supporting the use of higher natural background levels in its regional haze state implementation plan.