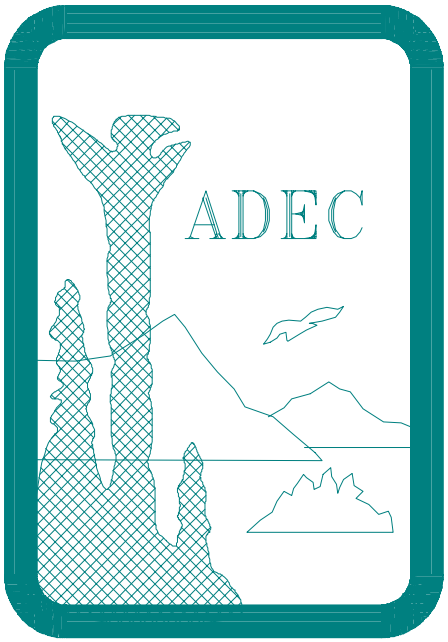
RURAL ALASKA DIESEL EXHAUST HEALTH IMPACT STUDY



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April 2007

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Acknowledgements

The research reported herein was performed by the University of Alaska and Alaska Department of Environmental Conservation. The Andreafski Tribe of Saint Mary's provided on-site project management. The Algaaciq Tribe of Saint Mary's provided on-site support. The Saint Mary's clinic provided space for lung health tests. The City of Saint Mary's provided space for the "City" monitoring site and assistance with site installations. The Saint Mary's School District provided space for the "School" monitoring site and construction of a monitoring shelter. Initial support in project planning was provided by the Alaska Native Health Board Epidemiology Section, now with Alaska Native Tribal Health Consortium. The Alaska Department of Transportation, Airport Maintenance in Saint Mary's provided assistance in shelter location and storage of monitoring equipment. Northern Air Cargo provided assistance heated storage for sensitive equipment before site installation.

Mary Ellen Gordian, M.D., Professor, University of Alaska, Institute of Circumpolar Health, was the principal investigator for health studies. Barbara Trost, M.S. Alaska Department of Environmental Conservation (ADEC) was principal investigator for monitoring activities. Project organizer and overall technical lead is Clint Farr, M.S., ADEC.

Executive Summary

In 2000 and 2002 the Environmental Protection Agency passed regulations to reduce the sulfur content in diesel fuel to an ultra low sulfur diesel (ULSD) for use in on road vehicles. Federal law required trucks and cars to use ultra low sulfur diesel by 2006 and non-road equipment after 2010. Alaska's plan was to shift ULSD in two phases; communities on the main road system, or with regular state ferry service, were to convert on-highway sources in 2006. Rural communities off the highway and ferry systems would delay conversion to ULSD for on-highway and non-road sources until 2010 to help alleviate some of the expected cost increase of ultra low sulfur diesel.

The health effects of diesel pollution are well-known in large urban areas where traffic produces most of the diesel exhaust. No studies have been conducted to determine if similar health effects occur in smaller Alaska communities. There is concern strong winter inversion conditions could keep diesel exhaust close to the ground and from dispersing. These inversions are common throughout the interior of Alaska. An association between the use of high sulfur diesel and increased respiratory illness in rural Alaska would influence local and state decisions on how to convert rural Alaska to use of ultra low sulfur diesel. In order to plan well for the conversion, a community would want to know how the new fuel will help them in terms of improved health, and what the cost increase will be.

To determine if using ultra low sulfur diesel will improve health in rural communities, the State of Alaska Department of Environmental Conservation partnered with the University of Alaska, Institute of Circumpolar Health, and the community of St Mary's to conduct a pilot study. The main objective was to determine if it is possible to identify potential health effects from exposure to diesel fuel pollution and test methods to uniquely identify air pollution from diesel exhaust.

The University of Alaska Anchorage conducted inhalation health assessments of volunteers, and performed indoor air quality monitoring. Health assessment methods included the volume of air one could forcefully exhale in one second and acidity of the condensate in exhaled breath. Indoor air monitoring occurred for elemental and organic carbon, as well as for volatile organic compounds. The health metrics were to be compared to both indoor and ambient air quality monitoring data to see if lung health might vary with pollutant type and concentration. In this study, no such relationships were found. We did find our monitoring and health assessment methods could be used in future rural Alaska health studies.

The Alaska Department of Environmental Conservation (ADEC) conducted ambient air quality monitoring in support of the health impact assessment. The objective for the ambient monitoring was to determine the ambient levels of diesel exhaust in the community during the winter months. Diesel exhaust consists of a mixture of many air pollutants for which there are no national standards. DEC decided to combine several instruments to evaluate diesel exhaust at all three of the monitoring sites: fine particulate matter ($PM_{2.5}$), black carbon (soot), Diesel Particulate Matter in form of elemental and organic carbon. Nitrogen oxides (NO_x), sulfur

dioxide (SO_2), and meteorological parameters like wind speed (WS), wind direction (WD), temperature (T), delta temperature (ΔT), ambient pressure, solar radiation and relative humidity (RH) were measured only at the School site to complete the pollutant analysis.

Measurements of the ambient air pollutants showed winter time ambient air in St Mary's is fairly clean. The levels for the three criteria pollutants, SO_2, NO_2 and $PM_{2.5}$ are typically below the instrument detection limit, and very low compared to the standards. Daily averaged black carbon concentrations fall in the range measured in other small rural communities around the country. Hourly values are elevated above background at times when wind is blowing from the power plant. These higher values do not indicate a strong pollution impact but do point to a single pollution source. Other black carbon sources like home heating exist in the community, and did not factor significantly into the data.

This project demonstrated the difficulty of completing health study tasks in rural Alaska, even with community support. Communities provided resolutions from three tribes and two city governments. Memorandums of Agreement were established with St. Mary's tribes, city, and school district. Locals were hired whenever possible. Despite this support, we were unable to generate enough participation of non-smokers to provide us with enough data to draw any conclusions on the impacts of diesel exhaust on health. We anticipated this might be the case, which is why we considered this research a pilot study. However, even getting enough participation to draw tentative conclusions on study methodology was difficult.

The purpose of the pilot study was to ascertain monitoring and health methods to develop a future, larger and more comprehensive study. However, this pilot study found no alarming health or monitoring results from the pilot study. Ambient results showed nothing near an exceedance of standards. Further, there has been a change in regulatory climate since the start of the study; EPA intends to regulate diesel burning sources that are common in rural Alaska. ADEC no longer recommends expending resources on peer review and future study as emissions of concern will eventually be controlled. This could change, however, if efforts to win exemptions from the federal fuel rules by some in rural Alaska prove successful.

CHAPTER 1 - INTRODUCTION AND RESEARCH APPROACH

Introduction

In 2000 and 2002 the federal Environmental Protection Agency passed regulations to reduce the sulfur content in unregulated diesel fuel to an ultra low sulfur diesel for use in on-road vehicles. Federal law required trucks and cars to use ultra low sulfur diesel by October 2006 and further required non-road diesel equipment (such as construction graders and bulldozers) to use it after 2010. Trucks made after 2006, and non-road equipment made after 2010, would not be able to use the older, higher sulfur, diesel fuel. Heavy duty on-highway vehicles, model year 2007 and later and 2010 model year and later non-road engines, will be outfitted with emission control devices that will reduce diesel pollution by over 90% when coupled with ultra low sulfur diesel. More recently, EPA promulgated rules to reduce emissions from stationary diesel sources, like power generators. These rules contain provisions lowering sulfur levels in diesel burned by regulated sources. Home heating fuels continues to be unregulated.

Alaska's plan was to shift to ultra low sulfur diesel (ULSD) in two phases; communities on Alaska's road system, or with regular state ferry service, converted on-highway sources in 2006. Rural communities off the highway and ferry systems will delay conversion to ULSD for on-highway and non-road sources until 2010. At the time of this study, the federal government had no plans to regulate the diesel burning sources common to rural Alaska; home heating and community power generators. The decision to have a one-step conversion on-highway and nonroad diesel fuel in 2010 was made to help alleviate some of the expected cost increase of ultra low sulfur diesel. Costs associated with refinery modifications necessary to remove sulfur, and the additional storage and distribution needed to keep ultra low sulfur diesel segregated from higher sulfur fuels, will be passed down to consumers.

The health effects of diesel pollution are well-known in large urban areas where traffic produces most of the diesel exhaust. No studies have been conducted to determine if similar health effects occur in smaller Alaska communities. Strong winter inversion conditions which could keep diesel exhaust from dispersing and close to the ground are common throughout the interior of Alaska. A high incidence of respiratory disease in children in rural Alaska also raises the question of air pollution exposure and impacts. In 2002, the Tribal Health Directors of the Alaska Native Health Board passed a unanimous resolution requesting that the Alaska Native Epidemiology Center undertake an investigation of the health effects of diesel and particulate air pollution.

An association between the use of high sulfur diesel and increased respiratory illness in rural Alaska would influence local and state decisions on how to convert rural Alaska to use of ultra low sulfur diesel. Rural off-road communities may use the new diesel sooner than 2010 if local circumstances, priorities, and economics allow it. This might happen, for example, if residents import 2007 model year diesel vehicles, which can only use the new fuel. Or a community may want to combine the use of ultra low sulfur diesel with emission control devices to realize the

full emission reductions. In order to plan well for the conversion, a community would want to know how the new fuel will help them in terms of improved health, and what the cost increase will be.

To determine if using ultra low sulfur diesel will improve health in rural communities, the State of Alaska needed to know if the current use of high sulfur diesel is causing health problems. The State of Alaska Department of Environmental Conservation partnered with the University of Alaska, Institute of Circumpolar Health, Alaska Native Health Board, and eventually the community of St Mary's to conduct a pilot study. Due to reorganization within the Alaska Native Tribal Health Consortium, participation with the Alaska Native Health Board ended before the study was underway.

Before we can identify potential health effects from exposure to diesel fuel pollution, we needed to try and test methods to uniquely identify air pollution from diesel exhaust, and identify health impacts that could be caused by diesel exhaust. This initial challenge formed the basis of the pilot study.

Background

Evidence of Health Effects from Diesel Exhaust

Diesel exhaust (DE) is composed of gases and fine particles. DE can irritate airways when inhaled at relatively high concentrations. At lower concentrations, DE causes the release of specific cytokines, chemokines, immunoglobulins, and oxidants in the upper and lower airway. These are proteins secreted from various cell types that mediate allergic and inflammatory responses. They can initiate a cascade of cellular processes culminating in airway inflammation, mucus secretion, serum leakage into airways, and contraction of bronchial smooth muscle (Pandya, RJ et al., 2002). Researchers have shown DE can increase the inflammatory response to allergens, (Diaz-Sanchez, D et al., 1994) and increase allergic reactions to new antigens (Diaz-Sanchez, D et al., 1999). Measurable impacts have occurred at concentrations comparable to a Los Angeles street side location.

Evidence for Health Disparities and Increased Respiratory Illness in Rural Alaska

The State of Alaska Section of Epidemiology studied respiratory illness in Nuiqsut and a control village (Serstad and Jenkersen, 2003). Both villages had populations of about 400 people. Forty-seven people in each village (11% of population in Nuiqsut, 12% in control village) had an asthma or reactive airway disease diagnosis. These people accounted for 84% and 87% of medical visits for respiratory disease in each village. In both villages, the most common respiratory diagnosis was asthma and the vast majority of the medical visits for respiratory disease were among those diagnosed with asthma. Although there is a general consensus that asthma rates are lower in rural areas than in urban areas, the actual rate is rarely published. One

study from New Zealand states that the rate for farmers in rural areas of New Zealand is 6.8% (Firth et al, 2001) which is about a half of what the Section of Epidemiology found in these very rural Alaskan villages.

Chronic respiratory disease is the most common health complaint in Alaska Native children. The prevalence of asthma is suspected to be increasing. Asthma is one of the few medical conditions that is not improving for Alaska Natives. An article in Alaska Medicine reported a 1997 survey of 465 Alaska Native children in grades 6-9 in the Yukon Kuskokwim Delta (YK Delta). Twenty-four percent (24%) had asthma or asthma-like symptoms, 37% were sputum producers, and only 39% had no respiratory symptoms (Hennessy, T. et al. 1999). There are numerous indications that asthma is an emerging health problem among American Indian and Alaska Native (AI/AN) children, and that it is often undiagnosed and inadequately treated (Hisnanick, et al 1994; Liu, et al, 2000).

The Yup'ik Eskimo have some of the highest rates of respiratory morbidity documented for any Native population. Hospitalization for respiratory syncytial virus (RSV) is five times higher for Native children in the YK Delta compared to the overall US population (156 vs. 31/1000) (Lowther, S.A., et al., 2000; Wright, A.L., et al.1989; Shay, D.K 1999; Karron, R.A., et al., 1999). During one recent RSV epidemic, one-fourth of all infants in this region were hospitalized at an estimated cost of $1034 per YK Delta child versus $27 per child in the rest of the United States (Karron, R.A., et al., 1999). Studies have also shown that bronchiectasis, a condition that has nearly disappeared in the industrialized world, remains relatively common among Alaska Natives in the YK Delta (Lewis, T. 1999; Stout, J et al 2001; Fleshman, et al 1968; Singleton, R., et al., 2000). The most common predisposing factor for bronchiectasis is having early and recurrent pneumonia, implicating increased susceptibility to respiratory infections in chronic respiratory symptoms.

Potential Air Pollution Exposures in Rural Alaska

Diesel use in home heating and power generation in rural Alaska may contribute to the incidence of asthma and other respiratory disease. However, there are many important confounding environmental exposures in rural Alaska. The largest of these is tobacco smoke. Smoking rates can be as high as one in two in some communities. In addition to cigarettes, wood-burning stoves are associated with higher indoor air concentrations of inhalable particles, increased risk of lower respiratory tract infections, and asthma exacerbations (Vedal, et al 1998; Morris, K., et al, 1990; Robin, L.F., et al, 1996; Wright, A.L., et al., 1991; Armstrong and Campbell, 1991). Exposure to volatile organic compounds (VOCs) also occurs due to storage of gasoline and solvents indoors.

Research Approach

The goals of the pilot study were to determining which parameters of respiratory health could be measured effectively and correlated with exposure to air pollutants. To test exposure we planned

to monitor ambient air and compare the values to data from personal monitors. As personal monitoring might proof not feasible, indoor sampling would be conducted instead. Diesel exhaust is often measured by sampling for elemental carbon. A comparison between ambient and indoor elemental and organic carbon was intended to distinguish between ambient and indoor sources of pollution, which might impact health. Volatile organic compounds would be measured as a potential confounder to diesel exposure. The occurrence of ambient and indoor pollution values would be compared health data, to determine if a health reaction was visible at the pollution levels detected in the community. A detailed health assessment and air monitoring study proposal was intended for peer review to help plan a main health impact study.

Community choice

The choice of host community was based on a number of factors. The number of residents in a community was a major initial consideration. A community must be large enough to ensure there would be enough study participants. The community should have weather and wind that would provide for a variety of exposure conditions to local diesel exhaust. We chose St. Mary's because the community had the potential for exposure to diesel exhaust based on wind directions, and the three governments in the community supported the project. Memoranda of agreement were set up with the two St. Mary's tribes, the city of St. Mary's, and the St. Mary's school district outlining participation and activities of the different organizations. A more detailed discussion of community choice efforts can be found in Appendix B.

Indoor Air Monitoring Strategy and Health Measurements

Institutional Review Boards

In order to work with human study objects, researchers must obtain approval from appropriate Institutional Review Boards (IRB). When a community was chosen, our health primary investigator started the process of getting IRB approval from the Yukon Kuskokwim Health Corporation (YKHC) and the University of Alaska Anchorage. We learned from YKHC we also needed approval from the Alaska Area Office of Indian Health Service. We obtained approval from the IRB of the University of Alaska Anchorage (UAA) and the Area Office within months of submitting the project plan. Approval from YKHC took more than six months.

Indoor Air Sampling

Environmental tobacco smoke is an important confounding pollutant exposure. Along with wood-burning stoves, cigarette smoking is associated with high indoor air concentrations of respirable particles and increased risk of lower respiratory tract infections and asthma exacerbations (Wright, A.L., et al., 1991; Armstrong and Campbell, 1991; Morris, K., et al, 1990; Robin, L.F., et al, 1996; Vedal, et al 1998). Because researchers are not able to separate tobacco and wood smoke from diesel exhaust, we looked for study homes with no smokers or wood burning. Ideally, a non-smoking, non-wood burning home would have given us an indication of the extent of exposure to particulate pollution most likely due to diesel exhaust.

Volatile organic compounds (VOC) have respiratory effects (Pappas et al 2000). Exposure to diesel fuel and exhaust include VOC exposures (Sydbom, A et al., 2001). VOC exposures also occur from gasoline which in Alaska contains as much as 5% benzene. Gasoline is often stored within the airspace of homes (Schlapia and Morris, 1998). We tested for personal exposure using passive badges. Passive badge monitors are easy to use and transport in remote areas. See Appendix B for more discussion.

Particulate pollution was measured by a diesel particulate matter (DPM) cassettes. Initially, these monitors were to be worn. However, the pumps were too noisy and indoor monitoring was conducted instead. The filters were analyzed for elemental and organic carbon. Concurrent ambient air monitoring was done by ADEC.

Health Measurements

Measuring nitric oxide in exhaled breath and the acidity of the liquid component of breath are attractive methods to measure health impact of air pollution exposure. They are non-invasive procedures that can be done by medical technicians with little training in remote areas (Baraldi, E. et al., 2003). Because exhaled nitric oxide samples could not be analyzed in Alaska, only breath condensate measurements were performed. Exhaled Breath Condensate (EBC) was collected for measuring pH as a measure of airway inflammation. It is a research health parameter that is thought to vary with asthma severity (Hunt, J. F. et al., 2000).

Airway restriction was measured by assessing the change in the forced expiratory volume in one second (FEV1) after use of a bronchodilator. FEV1 is a standardized method of assessing respiratory capacity approved by the American Thoracic Society and has been shown to vary with environmental exposures. For more discussion on FEV1, see Appendix B.

Conduct of the Health Study

Based on discussions and negotiations with EPA staff (See Appendix A) we decided our pilot study would be a panel study of people with asthma using personal monitoring for diesel exhaust. Participants recruited for the study had to have asthma, could not taking steroids, and lived in smoke-free homes. The purpose of these criteria was to ensure a study population sensitive to pollution exposures but free from exposure to confounding pollutants like cigarette smoke. Further, a study population of this sort would not have lung function influenced by medications. The study occurred during winter when potential for both indoors and outdoors exposure to diesel exhaust is highest due to the dark and cold increasing demand for electricity and heat.

We hired two local research assistants who lived in St. Mary's to do the field work. The research assistants were brought to Anchorage for two days of training. The training was provided by two outside trainers. One taught the assistants how to collect environmental data in homes, including calibrating pumps, using DPM cassettes and exposing VOC badges. A respiratory therapist from

Providence trained them in spirometry. This was practiced several times during the two days. For more discussion on hiring assistants and types of equipment used, see Appendix B.

Interested participants could speak to a medical researcher to determine whether they met requirements for participation. If a person decided to participate, they were asked fill out a questionnaire for baseline information. The questionnaire included inquiries about medications, co-morbidities, occupation, and other potential exposures to particulate or VOCs such as cooking, heating, and hobbies. Participants then signed informed consent forms and then learn to use the AirWatch portable spirometry unit, and breath condensate acidity tests. For more information on participant recruitment, see Appendix B.

The idea of using personal monitors to measure diesel exhaust exposure and VOCs was rapidly dismissed during the training program. The primary investigator and project staff found it difficult to carry the pumps on their person for even one day. The pump noise was intrusive. The primary investigator decided it was unlikely research subjects would wear these pumps on their person. The protocol was changed to measure indoor diesel exhaust, not personal exposure before data collection began. Pumps with DPM cassettes were placed in the main living area of the house for indoor monitoring.

The technician in St. Mary's set up the DPM cassette on a calibrated pump and took it to the subject's home along with an unopened benzene badge. The technician started the pump and opened the badge in the home recording both the number of the cassette and the number on the badge on an encounter sheet. On the day of monitoring, participants came to the clinic prior to taking asthma medication. The technician checked exhaled breath condensate acidity and FEV1 before and after use of a bronchodilator. The next day the technician returned to the home, collected the pumps, recorded the stop time and place the badges in the cans, covering them. The technician mailed badges and cassettes by air freight back to Anchorage on a weekly basis. For more information on the operation of the DPM cassettes and pumps, see Appendix B.

CHANGE IN STRATEGY

When it became clear participation in the panel study would be low, we decided it was important to survey of indoor elemental carbon. The local research assistant recruited participants to allow DPM measurements in their homes and public buildings. Over 30 locations including private homes, a school, post office, a store, and a tribal office were monitored. For comparison, indoor elemental carbon measurements were made simultaneously in 20 indoor locations in Anchorage, Alaska homes. The measurements in Anchorage focused on non-smoking homes which is standard for trying to measure elemental carbon derived from fuel burning sources. No questions about smoking or woodstoves were asked in St. Mary's.

Figure 1 - Aerial view of St. Mary's showing where the indoor monitors were placed.

VOC MEASUREMENT CHALLENGES

Passive absorption badges, called 3M organic vapor monitors, were co-located with DPM cassettes in many locations. The passive badges measured benzene, toluene, ethyl benzene and the xylenes. None of the badges were closed properly. However, badges were returned with canisters tops securely fitted. This was discovered after half of the badges were returned for analysis. The primary investigator determined the mistake resulted a consistent systematic error for all measurements, and elected to finish the collection using the same method the field technician used from the beginning. As long as the variance was high, the comparative measures would still be useful. See Appendix B for more discussion.

Ambient Air Monitoring

The Alaska Department of Environmental Conservation (ADEC) conducted air quality monitoring in support of the health impact assessment.

The objective for the ambient monitoring part of this pilot study was to determine the ambient levels of diesel exhaust in the community during the winter months and to test if this pollutant could be sufficiently identified amongst other possible pollutants. Diesel exhaust consists of a mixture of many air pollutants for which there are no national standards. No specific instrument exist to measures just diesel exhaust. Nationwide research has identified several chemical compounds which are considered surrogates for diesel exhaust, like diesel particulate matter (DPM) which is analyzed as elemental carbon (EC). And although elemental carbon is present in diesel exhaust, it is not unique to diesel exhaust alone, but can also be found in exhaust from other combustion processes.

DEC decided to combine several instruments to evaluate diesel exhaust at all three of the monitoring sites. Fine particulate matter ($PM_{2.5}$) was measured continuously with Thermo Scientific samplers (TEOM-FDMS). Black carbon (soot) was measured continuously with Magee Aethalometers. The aethalometer was equipped with a $PM_{2.5}$ cyclone inlet, limiting sample collection to fine particulates. Continuous measurements were paired with EPA Federal Reference Monitors (FRM) for $PM_{2.5}$ and filter based SKC Inc. Diesel Particulate Matter (DPM) samplers. DPM cassettes were analyzed for elemental and organic carbon following the NIOSH 5040 method. Continuous measurements of nitrogen oxides (NO_x), sulfur dioxide (SO_2), wind speed (WS), wind direction (WD), temperature (T), delta temperature (ΔT), ambient pressure, solar radiation and relative humidity (RH) were only measured at the School site to complete the pollutant analysis.

Site Description

To be able to collect sufficient health information for comparison to ambient pollutant levels DEC set the minimum community size limit at 500 residents. The other selection criterion was the dominant wind direction which could transport diesel exhaust into large parts of the community. Only very few communities fit these criteria. The governments in St Mary's expressed an interest in supporting the study and signed resolutions to this effect.

St. Mary's is located in western Alaska on the north bank of the Andreafski River, five miles from it's confluence with the Yukon River. The community has an estimated population of 570 residents (2005 State demographer estimate). Figure 2 shows two maps, the regional location of St. Mary's within Alaska on one of the maps, and a more precise location on the Andreafski River.

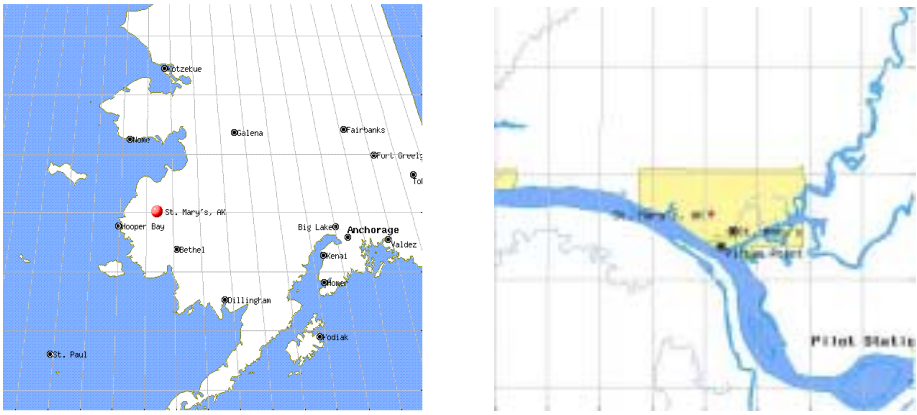

Figure 2 - Maps of St. Mary's location in western Alaska and on the Andreafski River.

St Mary's is about 450 miles west northwest of Anchorage. The climate of St. Mary's is continental with a significant maritime influence. Temperatures range between -44°F (-42°C) and 83°F (28°C). Annual precipitation measures 16 inches, with 60 inches of snowfall.

The city of St. Mary's is comprised of the Yup'ik villages of St. Mary's and Andreafski. The community and DEC identified ambient monitoring sites based on prevailing winds and source locations. One site was equipped with meteorological instrumentation to associate all air quality data with wind speeds and wind directions. This allowed us to determine micro scale wind patterns. Two sampling sites, named the 'City' and 'School' sites, were located in the St. Mary's village area, while the 'Town' site was in the Andreafski village area. St. Mary's is situated on a hilltop, hillside, and along the flat banks of the Andreafski River.

Figure 3: View of St Mary's from the west southwest.

The 'School' site was located on the edge of a ridge top at an elevation of 476 ft. The surrounding area is relatively flat with various mostly non-residential buildings. Dixon Circle Road runs north and Elementary Way runs west away from the site. School buildings and residences line either side of this road. To the south are two Quonset huts used by the village school. On the East side of the monitoring site the hillside slopes away toward the backside of several residences. The latitudinal and longitudinal coordinates are 62° 03.072N and 163° 10.821W.

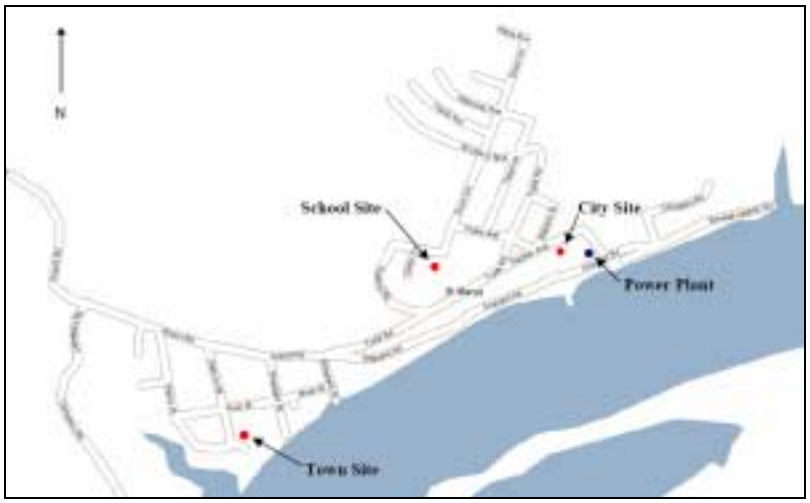

Figure 4: St Mary's street map with monitoring site locations and location of diesel power plant.

The 'City' site was located on a hillside at an elevation of 16 ft. Residences lie to the north of the site. To the east the hillside slopes away down to the backside of several warehouses and the village's power plant. To the south, the hillside slopes away toward the DOT warehouse. The City Hall and Algaaciq Tribal Government building lie to the west. The latitudinal and longitudinal coordinates are 62^{o} 03.095N and 163^{o} 10.476W. The 'Town' site is located near Alstrom Street at an elevation near sea level. Residences lie in all directions of the site. To the south, Alstrom Street runs east-west. The latitudinal and longitudinal coordinates are 62^{o} 03.095N and 163^{o} 10.476W. Potential major local pollutant sources for all three sites include the power plant, exhaust from home heating, wood smoke, and both diesel and gasoline vehicle exhaust.

Instrument Description

The Rupprecht & Patashnick Co. Series 8500 FDMS was used in St. Mary's to sample $PM_{2.5}$. The instrument is comprised of a Series 1400 Tempered Element Oscillating Microbalance (TEOM) and a Series 8500 Filter Dynamics Measurement System (FDMS). This instrument is a continuous analyzer providing hourly averaged values of base mass, reference mass and total mass concentrations.

The Rupprecht & Patashnick Co. Series 2000 Partisol is a manual filter based particulate sampler. It is the EPA Federal Reference Method used to detect fine particulate matter. A pre-weighed filter is installed in the sampler, which is pre-set to sample 24 hours from midnight to midnight. The exposed filter is shipped back to the DEC laboratory where it is reweighed to determine the change in mass. Based on this information and the data gathered by the instrument a 24 hour average concentration is calculated.

The *Aethalometer 2 series (AE2)* is a dual channel instrument that uses a continuous filtration and optical transmission technique to measure the concentration of black carbon (BC) in near-real-time. The second channel simultaneously measures the optical absorption of hydrocarbnons in the near ultraviolet. This instrument is a continuous analyzer providing hourly averaged values of black carbon mass concentration and a qualitative UV absorption signal indicating other carbonous compounds.

The SKC Inc. diesel particulate matter cassette sampler *(DPM) model 224-PXCR4* is a constant flow personal or area sampler. For this study a flow setting of 4 l/min was used to obtain samples for carbon analysis on 47mm filter cassettes. All samples were analyzed for elemental and organic carbon concentrations following the NIOSH 5040 method.

Sulfur dioxide was sampled with a Thermo Electron Corporation - TECO 43C monitor. This is a federal reference monitor based on detection by chemiluminescence. Nitrogen oxides were detected with a Thermo Electron Corporation - TECO 42C monitor, also based on chemiluminescence. The instrument provided hourly averages calculated form 5 minute sampling averages.

The meteorological parameters, i.e. wind direction, wind speed, temperature, relative humidity, solar radiation and barometric pressure were measured with RM Young sensors as one minute averages and stored as hourly averages in a H2NS data logger. Table 1 summarizes the instrumentation and the location in St Mary's

Table 1: AMBIENT AIR MONITORING PARAMETERS AND EQUIPMENT USED IN THE ST MARY'S STUDY

Parameter	Sites	Method
$PM_{2.5}$ FRM	all 3 sites, 1 site collocated (Town site)	R&P Partisol FRM 2000
$PM_{2.5}$ - TEOM-FDMSs	3 sites,	R&P FDMS 8500 with TEOM 1400a
Black Carbon	all 3 sites, 1 site collocated (Town site)	Magee Scientific Aethalometer w/BGI 2.5µm sharp cut cyclone (3 sites)
Elemental Carbon	all 3 sites, 1 site collocated (Town site)	SKC 224-PCXR8 Diesel Particulate Matter Cassette Sampler w/ quartz filter and 1µm particulate cut point
SO_2	School site	TECO Model 43C
NO-NO_x-NO_2	School site	TECO Model 42C
WS	School site	RM Young Model 05305VM
WD	School site	
Temperature	School site	RM Young Model 41342VC w/ 43408 aspirated radiation shield
Δ Temperature	School site	RM Young Model 41372VC w/43408 aspirated radiation shield
Relative Humidity	School site	
Barometric Pressure	School site	RM Young Model 61202V
Solar Radiation	School site	RM Young Model 70101

National Ambient Air Quality Standard

Under the authority of the Clean Air Act, the United States Environmental Protection Agency (USEPA) has issued air quality standards for public exposure to safe levels of criteria pollutants, i.e. Sulfur Dioxide (SO_2), Nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3), particulate matter (PM) and lead. The focus of these standards is the protection of public health and welfare. In this study, measurements of sulfur dioxide, nitrogen dioxide and particulate matter will be compared against the national standards. There are currently no standards for airborne elemental or organic carbon or any other diesel exhaust surrogates.

Sulfur dioxide (SO_2) sources are largely from stationary sources, like coal and oil combustion, industries, refineries and diesel engines. High concentrations of SO_2 affect breathing and may aggravate existing respiratory and cardiovascular disease. Sensitive populations include asthmatics, individuals with bronchitis or emphysema, children and the elderly. SO_2 is also a primary contributor to acid deposition, or acid rain, which causes acidification of lakes and streams and can damage trees, crops, historic buildings and statues. In addition, sulfur compounds in the air contribute to visibility impairment in large parts of the country. There are three National Ambient Air Quality Standards (NAAQS) for SO_2: an annual arithmetic mean of 0.03 ppm (parts per million), a 24-hour level of 0.14 ppm, and a 3-hour level of 0.50 ppm. The first two standards are primary (health-related) standards, while the 3-hour NAAQS is a secondary (welfare-related) standard. The annual mean standard is not to be exceeded, while the short-term standards are not to be exceeded more than once per year.

Nitrogen dioxide (NO_2) is emitted from any source that burns fuel such as automobiles, trucks, heavy construction equipment, farming equipment and residential heating. NO_2 can irritate the lungs, cause bronchitis and pneumonia, and lower resistance to respiratory infections. The major mechanism for the formation of NO_2 in the atmosphere is the oxidation of the primary air pollutant nitric oxide (NO). Because of the rapid conversion between nitric oxide and nitrogen dioxide the two compounds are often summed up as nitrogen oxides (NO_x). Nitrogen oxides play a major role in the atmospheric reactions that produce ozone (O_3). NO_x forms when fuel is burned at high temperatures. The two major emissions sources are transportation and stationary fuel combustion sources such as electric utility and industrial boilers. The health based standard (53 ppb) for NO_2 is based on the annual arithmetic mean.

Particulate matter (PM) is the general term used for a mixture of solid particles and liquid droplets found in the air. Particles can range in size from large specks of soot to fine grains of dust and have diameters about one-tenth the diameter of a strand of human hair. Fine particles ($PM_{2.5}$) result from fuel combustion from motor vehicles, power generation units, and industrial facilities, as well as from residential fireplaces and wood stoves. Coarse particles (PM_{10}) are generally emitted from crustal sources, such as vehicles traveling on unpaved roads, material handling, crushing and grinding operations, as well as windblown dust. In this study we focused on fine particulate. Fine particles are closely associated with increased hospital admissions and emergency room visits for heart and lung disease, increased respiratory symptoms and disease, decreased lung function, and even premature death. Sensitive groups that appear to be at greatest

risk to such effects include the elderly, individuals with cardiopulmonary disease, such as asthma, and children. In addition to health problems, PM is the major cause of reduced visibility in many parts of the United States. The National Ambient Air Quality Standard for $PM_{2.5}$ during the study was set at.65 µg/sm^3 for the 24-hour average. A revision of the national ambient air standards on September 21, 2006 strengthened the 24 hour standard to 35 µg/sm^3.

CHAPTER 2 - FINDINGS

Health Assessment Results

We did not collect enough health data to draw any conclusions on the impacts of diesel exhaust exposure in rural Alaska on health of people with asthma in the community. The primary reason was a lack of participation rather than problems with the health assessment or monitoring methods. The following summarizes the indoor monitoring and health assessment data we were able to collect.

Indoor Monitoring

Elemental carbon can be produced by a variety of sources. Indoor smoking, indoors open fires, and outdoor sources entering the house can contribute. Originally we wished to avoid sources that might confound our search for elemental carbon derived from diesel exhaust by avoiding smoking homes. This became impossible due to smokers living in nearly every St. Mary's household. The Anchorage homes that underwent testing were non-smoking homes. The following table compares elemental carbon levels between St. Mary's and Anchorage households.

Table 2: INDOOR CARBON MEASUREMENTS PERFORMED IN ST MARY'S AND ANCHORAGE IN 2006

	St. Mary's N=30	Anchorage N=20
Total Carbon	33 µg/m3	27 µg/m3
Organic carbon	31 µg/m3	27 µg/m3
Elemental Carbon	1.5 µg/m3	1.2 µg/m3

Comparing Organic Carbon and Elemental Carbon indoors with FEV1 and FVC

We were able to capture 25 days of measured indoor EC, and OC indoors and usable spirometry results. We compared total EC and OC levels, as well as ratios of the numbers, to the health metrics. We found no correlation between changes in personal average forced expiratory volume in one second (FEV1) or forced vital capacity (FVC) values and measured OC or EC. We used nonparametric tests, which were also negative.

The most important factor affecting the value of FEV1 is the size of the person. Hence absolute value of FEV1 is not attributable to environmental factors but to gender, height, age and body size. Researchers can use FEV1 to compare populations regarding exposure by assigning their subject a percent of a predicted value based on a standard person's height, weight, age and gender. Large people may have values over 100% of the predicted value, small people may be less than 100%. Percent predicted FEV1 tells whether the person's lung function is normal or abnormal for their body size. A normal value falls within two standard deviations of the percent

predicted FEV1. Percent predicted values are usually given in the spirometry reading if the height, weight, age and gender of the person are entered.

Local customs prevented our technician from asking participants about their height, weight and age. The values we have for FEV1 are the absolute value of the volume of air that is moved in one second by their lungs. The FEV1 values measured in this study have not been standardized. Because the values are not standardized we can only look for daily changes in each individual's effort.

We had 25 days of monitoring for which there were values for FEV1 and FVC, and indoor carbon measurements including elemental carbon (EC) and organic carbon (OC). We also had breath condensate pH for those days as well. There were five participants who provided health data. The average length of participation was five days. Because the respiratory data was not standardized to age, height and weight, it could not be combined.

Table 3: PANEL STUDY RESULTS

person	date	pH	max FEV1	max FVC	ECug/m3	OCug/m3	total carbon	EC/OC	Benzene ppb/hr
A	1/19/2006	7.7	2.284	2.314	0.47	23.0	23.0	0.0204	0.224
A	1/20/2006	7.6	2.876	3.142	0.46	20.0	20.0	0.0230	1.953
A	1/27/2006	6.6	2.769	2.975	0.46	19.0	19.0	0.0242	N/D
A	2/15/2006	8.0	2.652	2.873	0.86	21.0	22.0	0.0410	N/D
A	2/27/2006	7.4	2.671	2.790	0.80	24.0	25.0	0.0333	0.644
B	1/27/2006	8.0	1.273	1.731	0.45	20.0	20.0	0.0225	3.088
B	2/1/2006	7.9	1.378	1.754	1.20	42.0	42.0	0.0286	0.430
B	2/8/2006	7.9	1.311	1.830	2.60	57.0	50.0	0.0456	0.286
B	2/13/2006	7.7	1.349	1.924	1.70	19.0	21.0	0.0895	0.869
B	2/15/2006	7.9	1.388	1.816	2.30	24.0	26.0	0.0958	0.584
B	2/16/2006	7.7	1.396	1.896	1.40	23.0	23.0	0.0609	0.529
B	2/28/2006	7.8	1.352	1.904	0.77	25.0	26.0	0.0308	0.430
B	3/8/2006	7.9	1.444	2.022	1.40	47.0	49.0	0.0298	0.506
B	3/15/2006	7.8	1.370	1.929	0.26	31.0	31.0	0.0084	N/D
C	1/20/2006	8.2	1.484	1.913	0.47	6.9	6.9	0.0681	0.506
C	2/8/2006	7.5	1.547	1.756	6.30	58.0	64.0	0.1086	0.598
C	2/9/2006	8.3	1.410	1.577	0.48	6.8	7.3	0.0706	0.430
C	2/13/2006	7.7	1.606	1.946	5.50	35.0	40.0	0.1571	0.869
C	3/20/2006	7.9	1.326	1.545	5.80	84.0	90.0	0.0690	0.491
C	3/21/2006	7.5	1.394	1.577	0.23	26.0	26.0	0.0088	0.330
C	3/22/2006	7.6	1.359	1.572	11.00	45.0	56.0	0.2444	0.463
C	3/23/2006	7.6	1.489	1.674	9.00	40.0	49.0	0.2250	0.500
D	3/7/2006	7.8	3.483	4.572	3.00	50.0	53.0	0.0600	N/D
D	3/8/2006	7.8	3.535	4.681	0.26	35.0	35.0	0.0074	0.409
D	3/20/2006	7.7	3.527	4.455	0.45	51.0	51.0	0.0088	N/D

Benzene Results

The average indoor benzene from St. Mary's was 0.96 parts per billion per hour (ppb/hr), and the median was 0.59 ppb/hr. The minimum benzene value equaled 0.14 ppb/hr, and the maximum equaled 4.24 ppb/hr. These values are comparable to what has been found in Anchorage indoor VOC studies.

Ambient Air Monitoring Results

Data Capture

Site installation and instrument set-up and calibration occurred in January 2006. This report summarizes the results recorded between February 1 and April 30. Instruments were periodically taken off line for calibrations, maintenance and quality control checks. Some instruments due to malfunctions and broken parts. Table 4 summarizes the hourly data capture for the continuous instruments. According to EPA requirements, a valid hourly data point requires operation of the instrument for at least 45 minutes during that hour. Valid daily data points for particulate matter require no less then 23 hours per daily average (from midnight to midnight) and a 75 % capture rate for the gaseous pollutants.

Table 4: HOURLY AND DAILY DATA CAPTURE FOR MEASUREMENT PARAMETERS COLLECTED IN ST MARY'S

Site	Pollutant	Hourly data capture	Daily data capture
School site	NO	85%	79%
	NO_2	85%	79%
	NO_x	85%	79%
	SO_2	85%	79%
	$PM_{2.5}$ (continuous)	91%	78%
	FRM $PM_{2.5}$	N/A	33%
	BC (continuous)	90%	90%
	EC	N/A	60%
	TC	N/A	60%
City site	$PM_{2.5}$ (continuous)	94%	73%
	FRM $PM_{2.5}$	N/A	50%
	BC (continuous)	89%	90%
	EC	N/A	80%
	TC	N/A	80%
Town site	$PM_{2.5}$ (continuous)	66%	63%
	FRM $PM_{2.5}$	N/A	50%
	BC (continuous)	87%	90%
	EC	N/A	63%
	TC	N/A	63%

SAMPLING RESULTS

Sampling started at very low temperatures, with records showing lows of -25ºF, see Figure 5. The blue dots represent the ambient temperature at the School site. Over the course of the three months sampling project the temperature never rose above 40ºF, even as solar radiation (day light) increased steadily (pink bars).

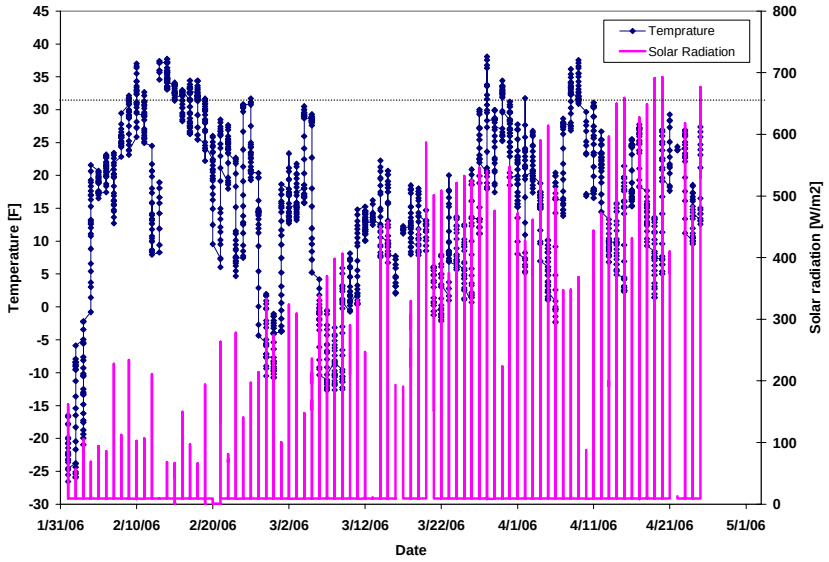

Figure 5: Hourly temperatures in degrees Celsius and solar radiation in W/m^2 recorded at the School site in St Mary's.

Gas Pollutant Monitoring

Measurements of nitrogen oxides and sulfur dioxide (Figure 6) were only performed at the School site and show few high hourly values. A majority of the data points were below the 10ppb detection limit of the SO_2 and NO_x instruments. Monitored values below the detection limit were set to half of the detection limit, or 5 ppb. Thus, the mean hourly mixing ratio for NO, NO_2, NO_x and SO_2 calculate to 5.6 ppb, 5.3 ppb and 6.6 ppb and 5.57 ppb, respectively. Because so few values are actually above the detection limit, the averages are also below the detection limit. For example, there were only 9 hourly values for SO_2 above the detection limit. Table 5 displays summary statistics for the measured gas pollutants. The complete data table can be found in Appendix C.

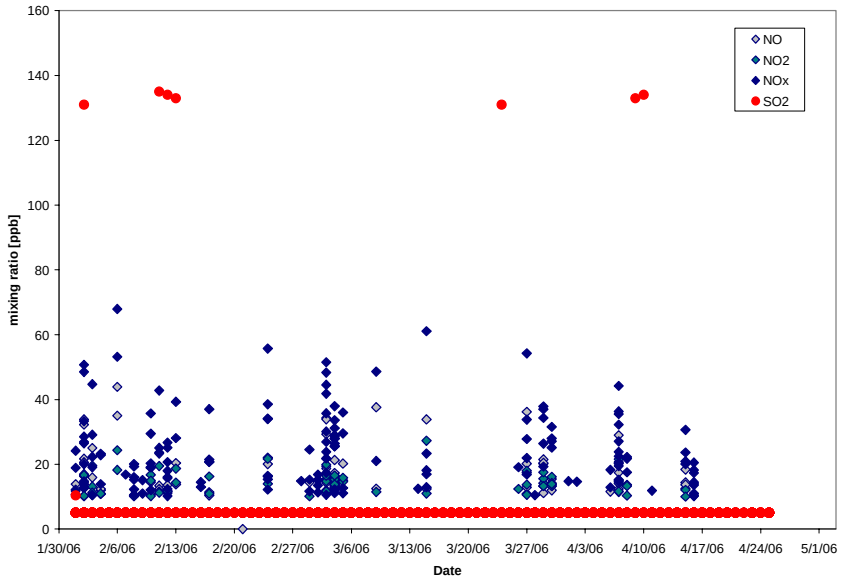

Figure 6: NO, NO_2, NO_x and SO_2, measured at the St Mary's School site

Table 5 : SUMMARY STATISTICS FOR GAS POLLUTANTS MEASURED AT THE ST MARY'S SCHOOL SITE

	NO	NO2	NO_X	SO_2
	[ppb]	[ppb]	[ppb]	[ppb]
Mean	5.63	5.39	6.60	5.57
Median	5.0	5.0	5.0	5.0
Standard Deviation	3.25	2.01	6.28	8.47
Minimum	0	5	5	5
Maximum	43.9	27.27	67.9	135

FINE PARTICULATE MATTER

Fine particulate matter was measured at all three sites continuously using a Thermo Scientific Tapered Element Oscillating Microbalance with a Filter Dynamics Measurement System. The system reports three mass concentrations: a base mass, a so called reference mass and a calculated the total mass.

The time series plot of all three sites is dominated by the measurements at the City site (Figure 7). The values recorded at the School site (blue squares) are typically lower than at the School site and thus are mostly covered by fuchsia colored diamonds from the City site. The green triangles represent the concentrations measured at the Town site. The TEOM/FDMS at the town

site had to be shut down due to instrument malfunction on February 28. Sampling resumed on March 29, 2006 after replacing a faulty valve.

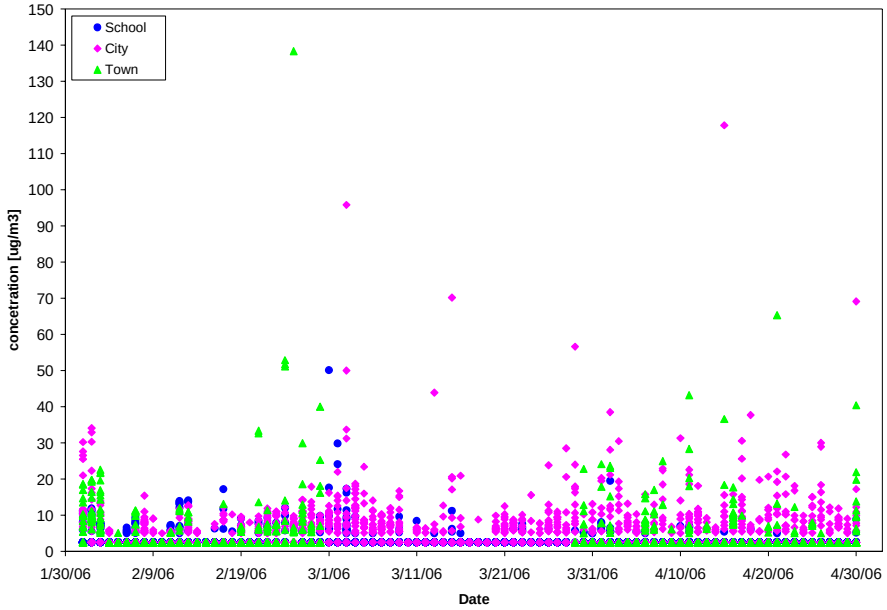

Figure 7: TEOM-FDMs Total $PM_{2.5}$ mass concentration for all three St Mary's sampling sites

The averaged hourly total mass concentrations for the three sites were 2.95 $\mu g/m^3$, 5.49 $\mu g/m^3$ and 4.09 $\mu g/m^3$ for the School site, City site and Town site, respectively. The majority of the values are well below 20 $\mu g/m^3$ at all three sites, with a few very high values close to 140 $\mu g/m^3$. The averaged hourly reference mass concentration at the School and Town site are slightly positive, with 0.47 $\mu g/m^3$ and 0.38 $\mu g/m^3$, respectively, which indicates that on average the volatile measurements were around the noise level of the instrument and not significant. The measurements at the City site on the other hand show a clear negative signal, which indicates a more consistent volatile component in the ambient air around the site. Table 6 summarizes the main statistical parameters of the continuous $PM_{2.5}$ measurements for all three sites. The complete data set is attached in Appendix C.

Table 6: SUMMARY STATISTICS FOR CONTINUOUS PARTICULATE MATTER MEASURED IN ST MARY'S

	School site			City site			Town site		
	Base Mass conc.	Reference Mass Conc.	Total Mass Conc.	Base Mass conc.	Reference Mass Conc.	Total Mass Conc.	Base Mass conc.	Reference Mass Conc.	Total Mass Conc.
	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3
Mean	2.86	0.47	2.95	4.93	-0.85	5.49	3.95	0.38	4.09
Median	2.50	0.60	2.50	2.50	-0.70	2.50	2.50	0.60	2.50
Standard Deviation	2.00	1.59	2.08	5.68	2.59	6.22	6.35	1.67	6.09
Minimum	2.50	-8.30	2.50	2.50	-32.40	2.50	2.50	-7.50	2.50
Maximum	50.10	4.70	50.10	111.90	4.90	117.80	138.10	4.90	138.30

BLACK CARBON

Black Carbon was measured at each site with a continuous two channel Magee Aethalometer. The first channel measures soot mass concentrations (carbonaceous particles, black carbon). Black carbon is often defined as the carbon measured by an aethalometer. It is closely related to elemental carbon but not identical. Although black carbon is often referred to as being primarily elemental carbon in the form of graphite, it is seldom pure and normally includes varying proportions of other elements. The second channel is a qualitative measure of other hydrocarbon compounds present in the air, which absorb ultra violet light. Because of the numerous possible hydrocarbons with unique absorption characteristics it is impossible to assign a concentration to the measured signal. Instead the difference between the UV signal and the black carbon concentration is viewed as a qualitative measure of other carbon sources, like wood smoke. A more detailed discussion of the aethalometer data will follow in Chapter 3.

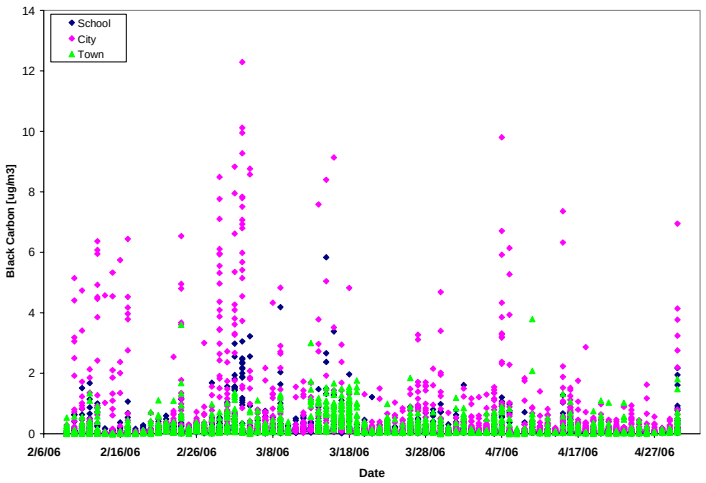

Figure 8: Black Carbon mass concentration measured at all three sampling sites in St Mary's

Figure 8 shows the time series for black carbon concentrations at the three sampling sites. The City site again reported higher concentrations than were measured at the School site or the Town site, both of which had very comparable results. The hourly mean for the School and Town site were 0.18 $\mu g/m^3$ and 0.19 $\mu g/m^3$, where as the City site recorded a mean of 0.58 $\mu g/m^3$. Table 7 summarizes the main statistical parameters of the continuous black carbon measurements for all three sites. The raw data is attached in Appendix C.

Table 7: SUMMARY STATISTICS FOR BLACK CARBON MEASURED AT THE ST MARY'S SCHOOL SITE

BLACK CARBON	***SCHOOL SITE***	***CITY SITE***	***TOWN SITE***
	µg/m3	µg/m3	µg/m3
Mean	0.18	0.58	0.19
Median	0.07	0.14	0.07
Standard Deviation	0.37	1.31	0.30
Minimum	-0.06	-0.01	-0.02
Maximum	5.84	12.29	3.80

CHAPTER 3 – DATA INTERPRETATION

Health Assessment

We achieved 5.5% of the number of data points we had anticipated for a meaningful panel study. There were only five participants in the panel study. The average participation was for 5.2 days. Spirometry was successfully done by non-medical personnel in the field. However, the results for each individual could not be combined because they had not been standardized. Local culture prohibited the research assistant from asking participants about their age, height and weight which would have standardized their spirometry results. Breath condensate was collected but the results showed no correlation with spirometry results. There was no quality control for breath condensate. High values could not be explained.

Elemental Carbon

We did not find a relationship between indoor or ambient air pollution levels and health outcomes in this limited study. Neither breath condensate, nor FEV1, correlated or varied predictably with measured elemental carbon or VOCs. We did find elemental carbon exposure indoors in St. Mary's are slightly higher than indoor exposure to elemental carbon in non-smoking homes in Anchorage and other urban centers in the United States. Though, the level is substantially less than elemental carbon measured in Hong Kong. We suspect second hand cigarette smoke to largely contribute to the increased level. It is also possible leaky furnaces and neighbor's woodstoves contribute to the increase.

TABLE 8: INDOOR ELEMENTAL CARBON MEASUREMENTS

Location	Elemental Carbon
Hong Kong	2.8 µg/m^3
Houston, Los Angeles*	1.1 µg/m^3
Anchorage*	1.2 µg/m^3
St. Mary's	1.5 µg/m^3

*both Houston, LA and Anchorage were non-smoking homes

Benzene

Indoor benzene was measured using passive absorption VOC badges. Badges were exposed for less than 24 hours in homes, they were than placed in cans with plastic lids and shipped to Anchorage by air freight. After collecting more than half of the badges, it was discovered that the plastic lids had not been put on the badges before putting them in the cans. We continued to collect badges in the same manner so that all results have the same systemic error. Because of this difficulty benzene levels may be biased to the high side. The highest levels did exceed ATSDR recommendations, however, because of the difficulty closing the badges the high levels would have to be reproduced. Multiple readings in the same house were not consistently high.

Ambient Air Monitoring Results

Compliance with National Ambient Air Quality Standards

Nitrogen dioxide, sulfur dioxide and fine particulate matter ($PM_{2.5}$) are the three measured compounds which are regulated by national health based standards. Table 9 summarizes pollutant levels and averaging times and the project results for the criteria pollutants measured in St Mary's.

Concentrations of sulfur dioxide were compared to the national standards. The 24-hour standard for SO_2 is 140 ppb and the study never found values exceeding 11 ppb, less than 1/10 of the daily standard. Most SO_2 data fells around the 5 ppb line. The project mean (3 month arithmetic average) was 5.46 ppb and is the only comparison we have to the annual standard. We expected the winter months to yield the highest SO_2 concentrations when power and heating needs are at their highest and pollution trapping inversions are the strongest. Comparing the conservative estimate for the project mean with the annual standard of 30 ppb we found SO_2 pollution levels to be low in St Mary's. The secondary 3-hour standard for SO_2 is 500 ppb; is ten times the measured three hour running average of 49 ppb.

Table 9: NATIONAL AMBIENT AIR QUALITY STANDARDS COMPARED TO LEVELS MEASURED IN ST MARY'S

Pollutant	Standard	Averaging Times	Measured in St Mary's.
Nitrogen Dioxide	53 ppb	Annual (Arithmetic Mean)	5.4 ppb (project mean)
Sulfur Oxides	30 ppb	Annual (Arithmetic Mean)	5.4 ppb (project mean)
	140 ppb	24-hour	10.4 ppb (max daily value)
	500 ppb	3-hour	48.3 ppb (max 3-hour average)
Particulate Matter ($PM_{2.5}$)	15.0 µg/m3	Annual (Arithmetic Mean)	5.4 $\mu g/m^3$ (max project mean)
	35 µg/m3	24-hour	11.3 $\mu g/m^3$ (max daily value)

The annual standard for NO_2 of 53 ppb is 10 times the measured project mean of 5.4 ppb. As with SO_2, we expect the project mean to be a conservative estimate of NO_2 levels throughout the year, as the main combustion sources in the community are linked to power production and home heating.

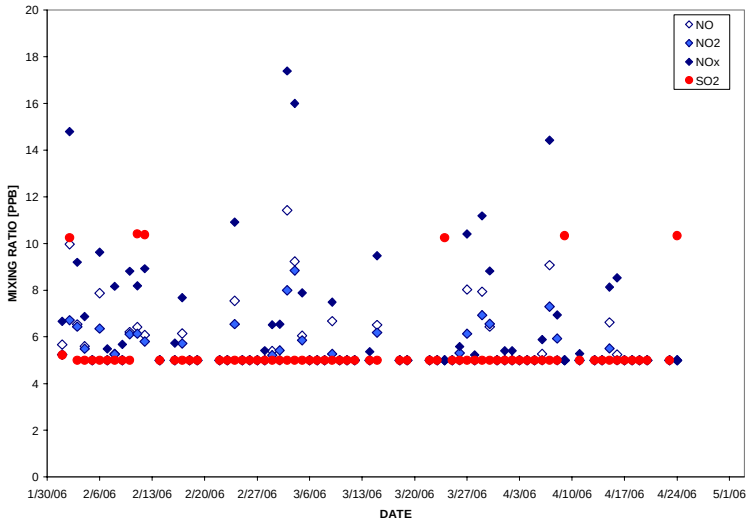

Figure 9: Time series of the 24 hour values for NO, NO_2, NO_x and SO_2 measured at the School site

The 24 hour fine particulate matter standard was revised effective December 18, 2006 from 65 $\mu g/m^3$ to a more stringent level of 35 $\mu g/m^3$. Although the study was performed before the standard went into effect we will use the more stringent level for our comparison. The maximum 24-hour value recorded was at the Town site with 11.3 $\mu g/m^3$ and the project mean for all three sites never exceeds 6 $\mu g/m^3$. Comparing the project mean with the annual particulate standard as a conservative estimate is not as straight forward as for the gaseous pollutants. Sources for particulate matter do not only include combustion sources from power generation, home heating and vehicle use, but also include burning landfills, wildland fires and burn barrels. This means that summer emissions of particulate matter can not necessarily be estimated to stay below the concentrations measured during this study. Although unlikely, it is possible that summer emissions can lead to exceedances of the 24-hour standard of add up to exceed the annual standard.

Carbon Data

As mentioned above there is currently no standard for black carbon. Daily averages measured in rural populated areas in the contiguous US commonly range from 0.1 $\mu g/m^3$ to 1 $\mu g/m^3$for areas not impacted by wood smoke. Smoke and diesel exhaust can impact even small communities and reach levels of up to 10 $\mu g/m^3$. Larger metropolitan areas like Los Angeles can reach up to 20-30 $\mu g/m^3$ on hazy or smoggy days. Typical average values for mid sized communities (up to 500,000 residents) are in the range of 5-10 $\mu g/m^3$.

Method comparison

One of the main objectives of this study was to determine if the instrumentation used would be adequate for investigating diesel exhaust exposure. For this purpose we paired federal reference

method and NIOSH samplers with continuous instrumentation to evaluate their performance. The federal reference method for particulate matter is based on 24 hour filter samples, which need to be analyzed in a laboratory. Similarly, the filters from the diesel particulate matter filters, are exposed for 24 hours and analyzed for elemental and total carbon. Continuous analyzers do not require lab analysis, offer hourly or shorter time resolution and the data is accessible almost instantaneously. This makes it easier to achieve high data capture as maintenance and operation is less intense as long as there are no instrument problems. EPA has not designated a continuous particulate monitor as a federal equivalent method (FEM) for fine particulate matter, nor is there standard equipment for diesel particulate matter, diesel exhaust or elemental carbon as a tracer for diesel exhaust.

Fine Particulate Matter

Fine particulate matter was measured using the filter based federal reference method (FRM) and the continuous TEOM-FDMS system. The federal reference method is based on a 24 hour filter sample from midnight to midnight, which is analyzed gravimetrically in a lab. The mass concentration from the continuous analyzer is averaged over the same 24 hour period for comparison. Figure 10 displays both the FRM concentration and the total mass concentration measured by the FDMS for the entire project. The FDMS measurements are marked by colored diamonds, the FRM measurements by colored Xs, according to the sampling site. A line at 5 $\mu g/m^3$ was drawn to show the method detection limit for the FDMS system.

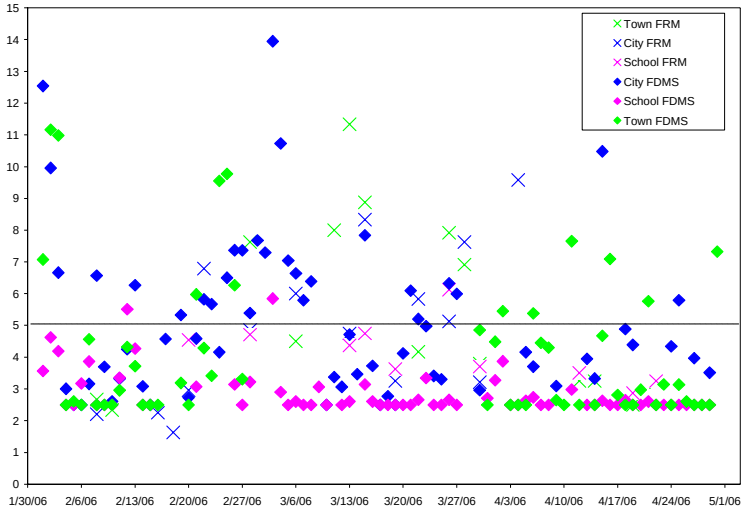

Figure 10: FRM and TEOM-FDMS $PM_{2.5}$ mass concentrations at all three sites in St Mary's.

As mentioned above the values encountered are fairly low and do not cover the full range of the instruments capacity. A correlation at the lower end of the concentration spectrum will produce skewed results, as much of the data is below the detection limit. Table 10 displays the main statistical parameters of the federal reference method and continuous measurements for all three sites.

Table 10: SUMMARY STATISTICS FOR FINE PARTICULATE MATTER CONCENTRATION MEASURED AT THE ST MARY'S SCHOOL SITE

PM2.5 Concentration	**Town** Site **FRM**	**City** Site **FRM**	**School** Site **FRM**	**City** Site **FDMS total mass**	**School** Site **FDMS total mass**	**Town** Site **FDMS total mass**
	($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)
Mean	5.4	5.0	4.2	5.1	2.9	4.1
Median	4.2	4.9	4.0	4.4	2.5	3.0
Standard Deviation	2.8	2.4	1.0	2.5	0.7	2.3
Minimum	2.3	1.6	2.9	2.5	2.5	2.5
Maximum	11.3	9.6	6.1	14.0	5.9	11.2

The Thermo Scientific FDMS system was chosen because it is supposed to capture the volatile component of fine particulates, which off gas of the filter of the federal reference method long before the filters are analyzed. To evaluate diesel exhaust, information on the volatile component might help distinguish diesel particulate matter from other fine particulate matter. The FDMS measures two mass concentrations, named the base mass and the reference mass concentration. The base mass concentration represents the mass concentration of particles that deposit on the balance after passing through a heated inlet line. The reference mass concentration is measured on the balance after passing through a chilled filter, which is supposed to trap all particles. During the two phase measurement cycle the volatile compounds deposited earlier volatilize off the balance and the detector records a mass loss, resulting in a negative mass concentration.

Figure 11 displays the base mass concentrations and FRM results on days for which samples from both methods are available. Initially the FDMS data storage was set up incorrectly and only recorded the total mass concentration. This explains the data gap at the beginning of the sampling period. The FDMS at the Town site had to be shut down because of instrument malfunction, which is why there are only a few data pairs for comparison at the end of the sampling period.

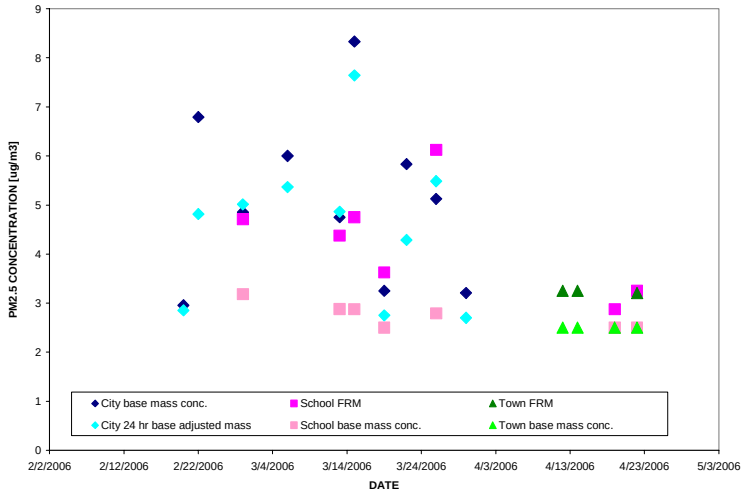

Figure 11: $PM_{2.5}$ base mass concentration and FRM $PM_{2.5}$ concentrations measured at all three sites in St Mary's

To calculate a correlation between the FRM and the FDMS method we used data from the City site, which had the widest range of results. Figure 12 shows the correlation between the base mass concentration and the total mass concentration measured by the FDMS and the FRM concentration. A linear regression (dotted line) shows good correlation between the base mass concentration and the FRM results (R^2 = 0.81). The correlation between the total mass concentration results and the filter results yielded a correlation coefficient of only R^2= 0.43. The lack of good correlation involving the total mass concentration indicates the importance of the volatile component of the particulates measured in St Mary's.

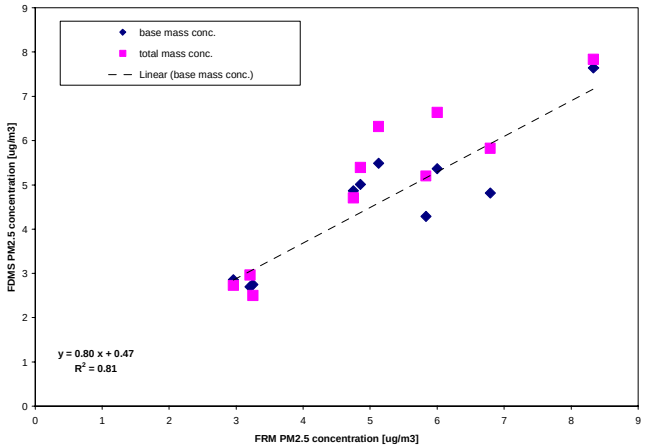

Figure 12: Correlation between FDMS base mass and total mass concentrations to FRM concentration measured at the City site in St Mary's

Carbon Measurement

Two separate methods were used to determine carbon concentrations in ambient air in St Mary's. Elemental and total carbon was measured using personal monitors set up to operate up to 24 hours by pulling ambient air through a filter. The filter was then analyzed following the NIOSH 5040 method for elemental and total carbon. Aethalometers were used for the continuous measurement of black carbon. The continuous data were averaged over the sampling period with the filter measurements for comparison. Figure 13 shows a comparison between the measured elemental carbon and black carbon at all three sites. Most of the values are very low, only four values measured above 2 $\mu g/m^3$.

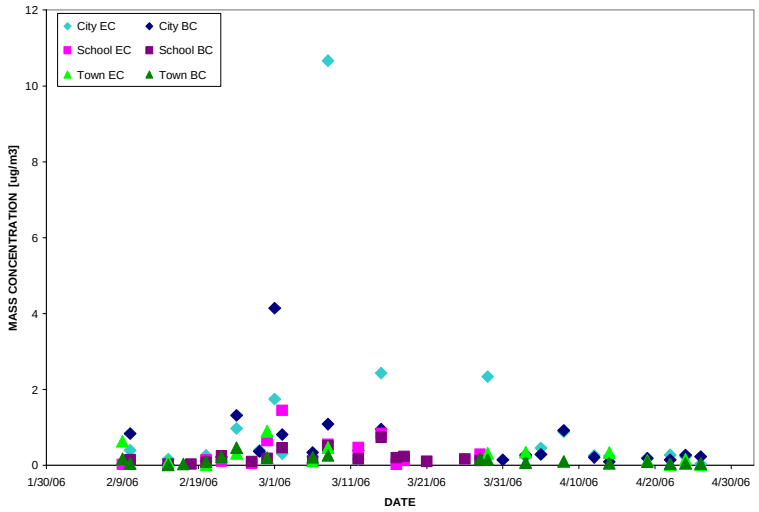

Figure 13: Time series of elemental carbon (EC) and black carbon (BC) measurements at all three sampling sites in St Mary's

Except for the City site, where higher values of both elemental and black carbon were recorded the methods seem to compare well. The data from the City site showed larger discrepancies. A reason for the closer comparison between the School and Town sites might be the carbon levels were fairly low and close to the detection limit. The SKC Inc. filter and pump set-up was intended as a personal monitor. The pumps did not hold up to the rigorous flow requirements associate with standard ambient air monitoring instrumentation. Although the pumps were repeatedly calibrated to produce a flow of 4 liters per minute (lpm) through the filter, tests at the end of the sampling period showed that the flow was unstable and varied from 2 lpm to 3.5 lpm, rarely performing at the set level. The unreliable flow creates a large uncertainty regarding the concentration. The aethalometer data showed quick data value swings in its 5 minute averages at the City site, which indicates a fresh carbon source near by. The large variability should be smoothed out, especially looking at 24 hour average, but might indicate why elemental carbon and black carbon cannot necessarily be expected to be treated as identical. A detailed discussion of the City site aethalometer will follow in the next section.

Site comparison

A comparison of the hourly average for particulate matter for the three sites does not show a significant difference in pollution levels. Overall the values are low. A comparison of the volatile component of particulate matter, called the reference mass concentration (TEOM/FDMS) showed a slightly higher contribution of volatiles and semi-volatiles to the fine particulate matter mass at the City site. Note a negative reference mass represents the mass loss due to off-gassing of volatile matter from the microbalance. A positive reference mass reflects instrument noise. Most of the data measured falls within the detection limit (± 5 μg/m^3) of the instrument and is not significant. Figure 14, shows the time series of the reference mass measurements. During the last month of the sampling period a significant volatile component of the fine particulate matter is visible both at the City and the Town site. The City site overall exhibits larger volatile mass concentrations than the Town site. A source for this volatile particulate mass could be fresh exhaust from home heating or the power plant or idling snow machines parked near the site.

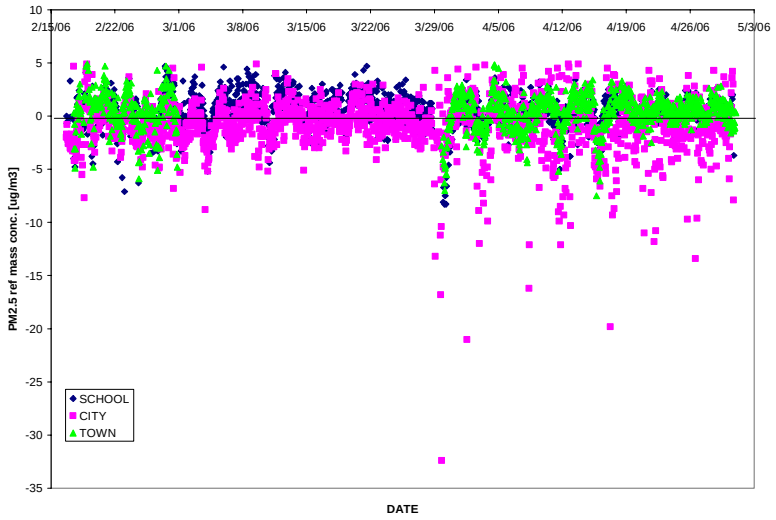

Figure 14: Time series of the PM2.5 reference mass concentrations measured at all three sites. A gap in the Town site measurements is due to instrument failure.

The only other significant difference between the sites is apparent in the carbon data. The gas pollutants were only sampled at the School site and thus do not aid in this analysis. Figure 6 shows the hourly values at the City site often exceed the values at both the School and Town site. The data averages show a three times higher mean concentration at the City site compared to the other two sites (see Table 7). To explore the reason for these differences we looked at diurnal data for each sites.

Diurnal Data

Analysis of the diurnal cycles of all the species measured at the three sites did not show a significant difference between the sites. None of the compounds showed a consistent diurnal trend at either site, which might help determine specific sources which influence one site but not

the others. Even though the values for $PM_{2.5}$ and black carbon are slightly higher on average at the City site, the concentration difference and diurnal variability do not show a clear pattern.

Wind Direction

To investigate differences between the sites, the site data were analyzed according to wind direction. Figure 15 shows the black carbon concentrations measured at all three sites as a function of the wind direction. The City site once again shows higher black carbon values across all wind directions. In addition, there is a significant cluster of highest concentrations mainly between 90 and 120 degrees, which is between east and east-southeast. The School site data is mostly drowned out by the higher values at both the Town and the City site. The Town site records its highest values between 60 and 90 degrees, which is from the east-northeast. Figure 4 shows a map of the community with the three sites highlighted in red and the diesel power plant marked with a blue dot. As can be seen, the power plant lies to the east-south east of the City site and the east-northeast of the Town site. Figure 16 shows the wind direction dependence of the gas pollutants at the School site. It also shows a cluster of highest concentrations around the eastern wind sector. On the other hand, graphing the total particulate matter mass concentration independent of the wind direction does not exhibit such a distinct cluster (see Figure 17).

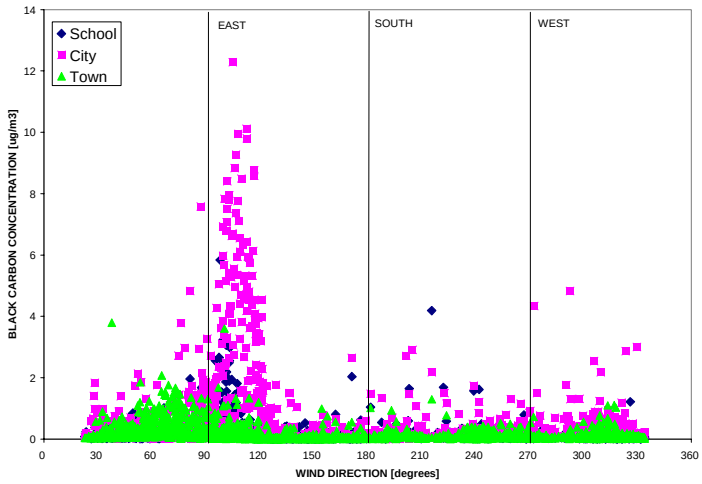

Figure 15: Black carbon concentrations measured at the three sampling sites in dependence of the wind direction. The x- axis displays the wind direction in degrees, where 90 degrees equals winds from the east.

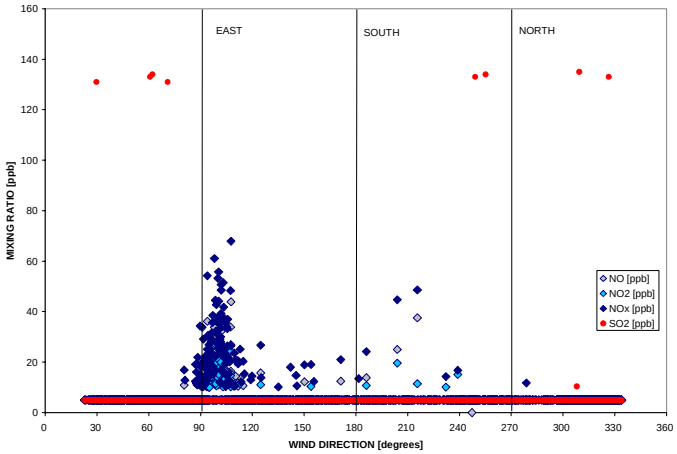

Figure 16: Gas Pollutant mixing ratios measured at the School sites in dependence of the wind direction. The x- axis displays the wind direction in degrees, where 90 degrees winds from the east.

It is to be expected that the largest single source contributes to higher pollutant concentrations within a wind direction sector compared to other potential sources, although the evidence is only circumstantial. Several factors play a role in pollutant levels, including proximity of the source to the sampler, source strength of the emitters and timeframe of the emissions. The power plant operates continuously around the clock. The other main diesel use of equivalent magnitude to the amount of diesel used for power production is diesel consumption for home heating. Home heating cannot be viewed as a single source, because the emissions are spread throughout the community.

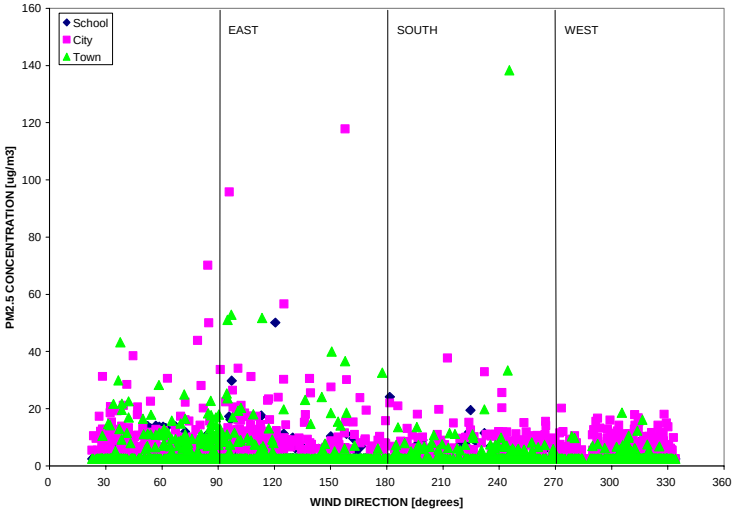

Figure 17: Total fine particulate matter mass concentrations measured at the all three sites in dependence of the wind direction. The x- axis displays the wind direction in degrees, where 90 degrees winds from the east.

Furthermore we analyzed the black carbon data using the difference of the measurements from the two channels of the aethalometer. The first channel quantitatively represents the black carbon (BC) concentrations. The UV channel qualitatively responds to other UV absorbing hydrocarbons. In general the UV signal should be larger than the BC signal. The difference UV-BC is often considered a measure for wood smoke or other non gasoline/diesel emissions. Figure 18 shows the time series of the hourly UV-BC signal for all three sites. Low negative UV-BC signals in the range of ± 0.5 μg/m^3 are most likely due to instrument noises. The large negative difference for the City site indicates fresh pollution. Even during the short 5 minute sampling times is the UV often smaller than the BC signal. This might be a function of instrument response time and chemical activity in the fresh plume. As fresh pollution is transported to the site fast chemical transformation and potentially changes in the source most likely cause the large discrepancy between the lower UV signal and the BC concentration.

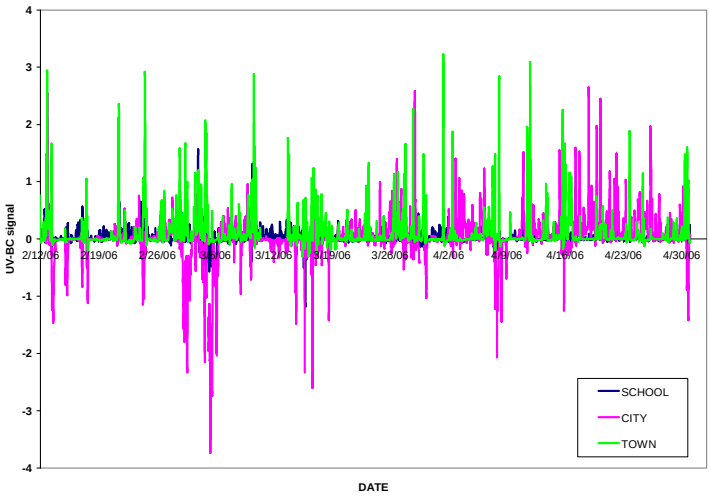

Figure 18: UV-BC signal measured with aethalometers at the three sampling sites in St Mary's.

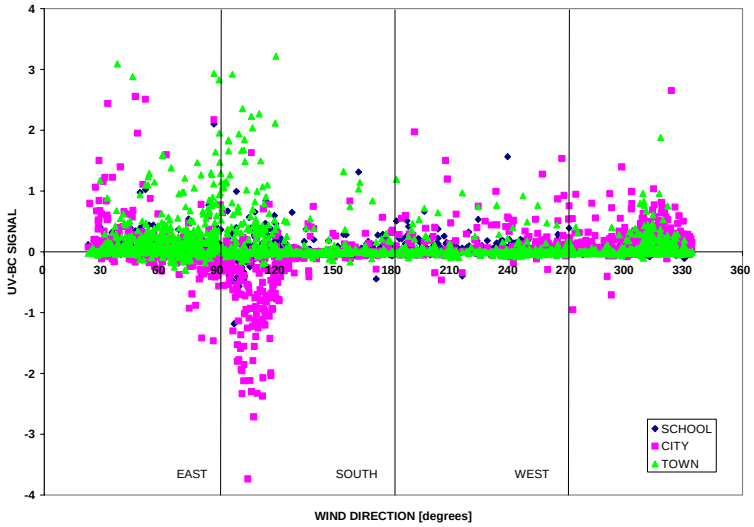

Figure 19: UV-BC signal according to wind direction, measured in St Mary's.

A closer look at the dependence on wind direction in Figure 19 shows that most of the large negative UV-BC signal values fall into the wind sector east to east-southeast. Again the main diesel exhaust source in that wind sector is the power plant. Thus is seems evident that the City site is exposed to fresh pollution of the power plant. As the plume travels to the other two sites further from the plant, chemical processes and dilution, i.e. aging of the plume is observed. It should be noted that even at the City site, which measured the highest black carbon levels, did the black carbon concentration rarely exceeded a daily average of 6 $\mu g/m^3$. As a comparison, values around these levels are is commonly found in larger metropolitan areas, which experience higher mobile source emissions and more diesel pollution. So even though the instrument detects fresh pollution from the power plant, the levels should not give rise to concern.

CHAPTER 4 - CONCLUSIONS AND SUGGESTED RESEARCH

Health Assessments

The acidity of breath condensate is considered a useful field measurement of airway inflammation in published literature. The literature suggests Argon be used to replace the air in the tube, which we did not do. We also did not measure the pH immediately, but sent the tubes to the University of Virginia for measurement. There was no quality control on the breath condensate as each sample required ten minutes to collect and we were reluctant to ask people to spend more time collecting repetitive samples. The results were not consistent. Some samples had high alkaline reactions, for which there was no explanation. Breath condensate was not difficult to collect, but it did not result in any useful information. We would not suggest its use in future research.

Spirometry was the other objective health measure we decided to use. Spirometry is available as software on a laptop computer. Our St. Mary's technicians were trained by a respiratory therapist from Providence Hospital in Anchorage. They learned to get consistent and acceptable results. The technicians performed the tests without supervision in St. Mary's. There was one result with a high and unexplained discrepancy where the subject's FVC was 4 times higher than their original test. All further results were consistent and appropriate. The spirometry results were useful as there was sufficient variation in daily results. Unfortunately, there were just too few data points to determine any correlation with environmental changes. The results did show that spirometry can be done by non-medical personnel in remote areas.

Personal exposure monitors proved unsuccessful in rural Alaska. Personal health study that requires the cooperation of participants is not easy to conduct in rural Alaska. There was little resistance to allowing the pumps to run inside the homes, but personal monitoring was not feasible. As a result the sampling for elemental carbon indoors was successful. However, it's usefulness as a surrogate for diesel exhaust is questionable due to the pervasiveness of confounding pollution sources such as smoking and use of wood stoves. VOC sampling was conducted in homes rather than as personal sampling. All of our VOC data however is questionable because the caps to the VOC badges were left mistakenly ajar. This could be corrected in the future with more training on the use of the VOC badges.

The following table summarizes what we planned to do in the pilot study, and what logistical realities allowed us to do.

Table 11: COMPARISON OF PLANNED HEALTH ASSESSMENT ACTIVITIES AND WHAT ACTUALLY HAPPENED

What We Wanted To Do	What We Did
Indoor monitoring for diesel exhaust, carbon monoxide, nitrogen dioxide, and volatile organic compounds	Measured indoor levels of elemental and organic carbon, and volatile organic compounds
Panel study with personal monitoring of person with asthma who were non-smokers and who agreed to the assessment	We could not find enough participants and opted to measure as many homes as possible. We then assessed the homes of anyone agreeing to an assessment. We did not check for smoking or woodstoves.
Personal monitoring using badges attached to pumps	Indoor monitoring was done for diesel exhaust and VOCs.
Personal monitoring of particulate matter using a personal nephelometer	No personal particulate monitoring conducted with a nephelometer. Early on we decided to try diesel particulate matter cassettes instead
Measure exhaled nitric oxide from subjects	Exhaled nitric oxide not used as it was determined to be logistically impossible
Measure for fine PM with diesel particulate matter cassettes	This was performed
Measure acidity of exhaled breath condensate	This was performed
Measure Forced Expiratory Volume	This was performed

Summary

The panel study had insufficient power to detect a health effect for either benzene or diesel exhaust. Respiratory testing is possible in remote locations. Efforts to measure breath condensate did not add information.

Ambient Monitoring

Measurement s of the pollutants showed that the winter time ambient air in St Mary's is fairly clean. The levels for the three criteria pollutants, SO_2, NO_2 and $PM_{2.5}$ are typically below the instrument detection limit, i.e. very low compared to the standards. Daily averaged black carbon concentrations fall in the range measured in other small rural communities around the country. On a shorter time scale the data indicates a distinct black carbon source most likely the power plant. Hourly values are elevated above background at times, when wind is blowing from the power plant. These higher values do not indicate a strong pollution impact. Other black carbon sources like home heating exist, but do not factor significantly into the data.

The instrument comparison between the two fine particulate matter sampling methods is inconclusive because of the overall low $PM_{2.5}$ concentration. The data is not spread out enough

to calculate a meaningful comparison. The comparison between the black and elemental carbon measurement methods showed that the personal monitors (DPM cassettes) do not withstand the rigorous quality control regime imposed on ambient monitoring methods. In the future different sampling methods should be explored to compare indoor/personal sample results to ambient monitoring.

General Conclusions

Recruitment was done with posters, announcements, and word-of-mouth. Either there were very few people with asthma who did not smoke in the community, or they were not interested, or we did not reach them. A total of five people were recruited, and only three of them were Alaska Natives. Posters were placed in the clinic, the store, the tribal offices, and the post office. Announcements were made at town meeting, clinic staff meeting and at the school assembly. The primary investigator set up the school meeting, presented an educational program on air pollution and asked for volunteers. Only one of the students did not smoke and in the end only participated for two days. The primary investigator also recruited a health provider at the clinic who was met at the airport. This person participated for five days. It is likely our incentives were too low ($25 for the first visit than $10/day). In any future study, we reexamine higher incentives. Repeated personal breathing tests by participants met with significant resistance.

In filling out the questionnaires, the technicians were extremely reluctant to ask anyone their age. They also did not ask for height or weight. This is likely a belief that this information is nobody's business. This did not confound the research effort as we were looking for interval changes. It did mean we did not get information to compare respiratory function to the norms for age, height, and weight. Finally, the inability to find a significant number of non-smokers suggests one clear thing. The rate of smoking in rural Alaska is a significant health risk.

The purpose of the pilot study was to ascertain monitoring and health methods to develop a future, larger and more comprehensive study. In the initial design phases for this study, we did not anticipate stationary source diesel engines would be regulated similarly to mobile source diesels. If results from our health study efforts showed a relationship between diesel exhaust and health impacts, ADEC could have acted to reduce stationary source emission. However, EPA did issue a final rule to control stationary source diesels. This important change in the regulatory climate, combined with no ambient or indoor monitoring results showing exceedance of any standards, ADEC does not recommend expending resources on peer review and future study. Instead, ADEC intends to focus on dust where exceedances have been measured in many communities. This recommendation could change however if efforts by some in rural Alaska to win exemptions from the federal fuel rules prove successful. The following briefly summarizes what we learned and would apply to any future study design should it be necessary.

Analysis of original study designs

EPA and the Alaskan researchers initially reviewed three study designs: cross-sectional, a panel case-control, and an intervention (See Appendix A). From what we learned in the pilot study, what can be said of the three designs and their utility in the future?

A big consideration is allowing children into the study. Two of the three study designs specified children as subjects due to a lesser influence from cigarette smoke. However, it became clear through difficulties in getting IRB approval that working with children may not be allowed. Use of the study designs would have to focus on non-smoking adults.

The second consideration was sample size. Capturing intra- and inter-individual variability in health measurements was necessary if we wanted to make data-based estimates of the appropriate number of participants for a future study. The pilot study did determine a high variability in health test results. Yet, even so, recruiting an adequate number of subjects willing to undergo numerous lung function tests is not likely. In the pilot study, we were only able to recruit 5 non-smoking adults who successfully made it through nine days of study. Each of the initial study designs would need many times that number of participants and longer study durations.

Except the idea of personal monitoring, we did find our analysis methods and data assessment would work in future studies. We kept our health metric tests, monitoring methods, and data analyses relatively simple which should translate well in any future studies. Use of monitors in homes can be done successfully. For a duration of a few months, our pilot study found that with the right local researcher encouraging people, indoor monitoring can occur.

The pilot study did show our instrumentation works, and we can successfully assess health using field measurements. On the other hand, the pilot study showed that recruitment of subjects as specific as adult, non-smoking, asthmatics may simply not be feasible in Alaska's villages. This makes the prospect of future studies, possibly involving hundreds of participants, difficult to imagine.

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Appendix A - Study Designs Assessed

Toward the end of 2003 and through the first three months of 2004, ADEC met with a group developed by EPA Region 10 to review study designs and identify funding sources for a health study. US EPA Region 10 representatives included Peter Murchie, the lead representative for USEPA and primary organizer of the review team, Mary Manous, Julie Wroble, Wayne Elson, John Pavitt, Mary Manous, and Keith Rose under the management of Jeff Kenknight, Jan Hastings, and Marcia Combes. Representatives from US EPA's of Air Quality Planning and Standards Organization included Jaime Pagan and Sims Roy, who was lead for the internal combustion engine MACT and NSPS standard, under the management of Penny Lassiter. Representatives from US EPA's Office of Research and Development included Charles Ris of the National Center for Environmental and Ronald Williams of National Exposure Research Laboratory. Representatives from US EPA's Office of Transportation and Air Quality included Chad Bailey, Marion Hoyer, Richard Babst, and Joseph Somers under the management of Paul Machiele. Also included was Richard Kauffman, a toxicologist with the Agency for Toxic Substances and Disease Registry, Region 10.

This group reviewed a number of health study designs. The three predominant designs closely scrutinized for viability were a cross-sectional study, a longitudinal & case-control study, and an intervention study. The following table summarizes these study designs.

Table 12: COMPARISON OF POSSIBLE HEALTH STUDY DESIGNS

	Original	**Panel Case-control study**	**Intervention[a]**
Type of study	Cross-sectional	Longitudinal & case-control	Experimental –pre-intervention is control
subjects	School age children	Children & adults	School age children
Expected number of participants	300	30 matched subjects, 60 days for time series	Less than 300 as some will not do follow-up
Analysis methods	Observational, correlation, multiple regression	Time–series analysis, t-test for matched groups, logistic regression ?	t-test for matched groups
Outcomes	Diagnosis of asthma, spirometry, breathe condensate, # of symptoms & medical visits for resp illness.	Respiratory event to be defined. Peak flow, symptoms, medical visits for respiratory illness	Unclear, probably symptoms, spirometry and breathe condensate, symptom reports, medical visits for resp illness.
Exposures to be measured	In-home diesel exhaust, particulate matter, VOCs, CO, CO2, temp, humidity	Same for 60 homes, but repeated every day, for 6 weeks for panel members.	Same done before and repeated after intervention.

	Visible mold for 300 homes. Ambient air in neighborhood measurements.		
# of days of measurements	Total=300	Total=1830	Total=600
Advantages	Use GIS for spatial analysis of ambient contributions.	Can use personal monitors for exposure to fine particles.	Strongest design to test whether changing diesel makes any difference.
Disadvantages	Weakest design for answering question of health effects of diesel exhaust.	May not have the power to answer question. Based on the experience of a small number of people, therefore less community buy-in for results.	Very expensive and difficult to implement, may not have sufficient power to answer question and could give participants false confidence of no effects. Does not take into account changes over time.
Cost	$250,000 +/-	$350,000 +/-	$3,000,000 +/-

a) Intervention study would involve looking at health outcome before and after intervention, the nature of the health measurements is the same as detailed in the original proposal.
Many EPA comments followed.

Because rural Alaska's population is sparse, exposures are unknown, exposures to confounders unknown, and the utility of research methods in these conditions is unproven, a pilot study was proposed to establish methods to then gather baseline health and air quality data. The baseline data would be used later to plan a more detailed study for peer review and implementation.

Appendix B - Data Collection Details

Community choice

The choice of community to host the study depended on a number of factors. The number of residents in a community was a major initial consideration. A community must have enough people to ensure there would be enough study participants, and enough variability in response to pollutant exposure, to reach statistically valid conclusions. On the other hand, too large a community would remove us from the population and community setting we wished to assess. Initially, we desired to work in a community of greater than 3000 people. This limited the number of communities available and we lowered our threshold to 500 people or more. Thus, we assessed nearly 50 communities with populations greater than 500 for proximity to the road and ferry system, wind speed, wind direction, and community layout. We also determined levels of rain and snow. Communities with heavy rain and snow likely have less exposure than drier areas. We wanted a compact community instead of a community with satellite residential areas. The chosen community must also be reliant on diesel power generation and must be off the state road or ferry system. We looked for communities with varied weather and wind patterns so there would be days when winds carried diesel exhaust in and out of residential areas. This allowed comparison of health measurements made on days with and without exposure. The community must have access to a local or regional health aid willing to help with the project. People in the community must have the time and commitment to be contacts and workers in lieu of researchers living in the community. Finally, the community must have been willing to host the study.

Nearly ten communities met our criteria after the initial look at location, weather, wind, and layout. We needed to determine the willingness of these communities to host the study and work with us. ADEC sent letters to these communities asking for a statement of interest in November 2004. Depending on the response to these letters, we were prepared to further rank communities based on ease of access and whether or not the community had mobile diesel sources which would confound attempts to determine diesel exhaust from power plants.

We received two letters in response to our inquiry of interest. We added more communities to a final list of communities to assess due to known interest or existing contacts. We acquired maps and detailed wind roses for these communities. We further narrowed the choice to a group of three villages in Southwest and Western Alaska. ADEC and UAA staff traveled to the three communities to ascertain if the community be willing to work with us and had health personnel available to assist in the study. Two communities in particular were willing to support the project. Support was demonstrated through tribal and city resolutions which are on file. The final choice of community was based on which had the most potential for exposure based on wind direction.

Health Assessment and Personal Monitoring Methods

Hiring Staff

We hired two research technicians who lived in St. Mary's to do the field work. We used the University of Alaska job description for a research technician grade 76. The pay rate included a cost of living adjustment for being in St. Mary's. Since unemployment is a problem in rural Alaska especially in the winter, we expected a large number of applicants. We had two. Neither applicant had post-high school education or research experience which we was a requirement for a grade 76. One person was immediately disqualified for previous job performance. The other person had a good work history. As we wanted two people (we expected to have ten subjects collecting data every day for two weeks) we asked our applicant if their spouse might be interested. Both received training so they could help each other should one become ill or there were too many people to visit in one day.

Participant Recruitment

Recruitment was done with posters, announcements, and word-of-mouth. Either there were very few people with asthma who did not smoke in the community, or they were not interested, or we didn't reach them. A total of five people were recruited, and only three of them were Alaska Natives. Posters were placed in the clinic, the store, the tribal offices, and the post office. Announcements were made at town meeting, clinic staff meeting and at the school assembly. The primary investigator set up the school meeting, presented an educational program on air pollution and asked for volunteers. One teacher and three high school students indicated they would participate. The teacher never came in for their appointment; of the three students only one was a non-smoker. The student non-smoker only participated for only two days. The primary investigator also recruited a health provider at the clinic who was met at a airport. This person participated for five days. It is likely our incentives were too low ($25 for the first visit than $10/day). In any future study, we would budget for higher incentives; however, too much financial incentive might result in non-eligible persons lying about their eligibility. Repeated personal breathing tests by participants met with significant resistance.

Participant qualifications

Participants were chosen based on whether they had a diagnosis of asthma or reactive airway disease, were at least 18 years old, did not require oral or inhaled steroids, and were living in a house where smoking is not permitted. A notice was posted in the community center and our local Community Health Aide was asked to notify persons with asthma who live in the community.

Personal monitoring

Initially, we considered measuring particulate pollution with a personal nephelometer. Nephelometer data would be immediately available and did not require further analysis. Unfortunately, funding and logistics did not allow the use of the nephelometer and we decided to use a filter based method instead. Initially, we expected that participants would be asked to carry

in a shoulder pack containing a DPM cassette which captured fine particulate matter (PM2.5) onto a filter. Attached to the pump would be 3M 3500 passive badges which measure benzene, ethylbenzene, toluene, and xylenes (BETX) by adsorption. Personal monitoring was never attempted because the pumps were too noisy. Pumps were placed in the main living area of the house for indoor monitoring instead.

We ordered AirLite pumps from SKC, Inc. They weigh 12 ounces and run on three AA batteries which usually allowed them to run for 24 hours or more. The average length of a run was 19.6 hours, 46% ran more than 23 hours. The average run length for the asthma study subjects was 21.6 hours and later in the study the technician started collecting the pumps earlier reducing the run time. The pumps sometimes stopped intermittently. Three pumps were returned to the company for servicing because of this. SKC, Inc. concluded the batteries were weak, but the problem seemed to only affect certain pumps.

Elemental carbon was measured using diesel particulate matter (DPM) cassettes with quartz filters. The flow rate was calibrated to be about 2 liters of air per minute. A calibration was done at the beginning and at the end of a run, and an average flow rate multiplied by the length of time in minutes was used to calculate the volume of air passing through the filter. The intact cassettes were mailed to DATACHEM laboratory in Salt Lake City. The EPA approved method for measuring elemental and organic carbon called NMAM 5040 was the method used to measure diesel exhaust. The first 10 samples were taken drawing air through the filter through a small central opening, but the laboratory called and asked us to collect future samples on an open filter because at the low levels we were measuring the small opening created an uneven distribution of the amount of carbon that we were collecting. The rest of the samples were than collected with an open cassette method.

National Institute for Occupational Safety and Health protocol for measuring BETX was used. The charcoal filters were extracted using 1 mL of CS_2 containing 5 ug/mL 4-bromofluorobenzene as the internal standard (ISTD). Extraction solvent was freshly prepared for each set of samples analyzed. We placed each charcoal pad inside a 2 mL amber vial, added 1 mL of the extraction solvent and closed the vials with Teflon lined caps. The pads were desorbed for 40 min in an ultrasonic water bath maintained within 15 to 18°C by adding small amounts of ice. After sonication, technicians withdrew the extract and transferred it to an amber autosampler vial. Working analytical standards in the range of 0.1 to 10 ug/mL were prepared using the solvent plus ISTD for dilution of commercial standard solutions. Technicians used a Varian 3800 Gas Chromatograph equipped with a Varian 2200 Ion Trap detector to analyze all extracts and standards. Separation was accomplished using an RTX-1 60 m x 0.25 mm id column with a 1 mm film thickness. Dr. John Kennish, professor of chemistry, University of Alaska Anchorage, performed this work at the ASETS laboratory.

VOC Measurements

Passive absorption badges, called 3M organic vapor monitors, were co-located with DPM cassettes in many locations. The passive badges measured benzene, toluene, ethyl benzene and the xylenes. Good quality assurance requires careful and proper transport of badges as they are

easily contaminated. The 3M 3500 passive badges give results adhering to National Institute for Occupational Safety and Health (NIOSH) acceptability criteria of 25% accuracy.

Challenges occurred with the volatile organic compound monitoring. None of the badges were closed properly. This was discovered after half of the badges were returned for analysis. The excess exposure occurred while the badges were being held in their cans by the primary investigator. As data collection was well underway, the primary investigator decided to measure how much exposure would have occurred while the badge was in the can. Two badges were exposed to a low benzene environment, and two to a high benzene environment. In each set, one badge was exposed in the can with the top off, and the other was opened but put in the can with the top on (which is the way the badges were being returned). By putting the top on the can, 90% of the exposure was eliminated. Removing the faceplate and placing the plastic cover over the badge, which is the suggested way to ship the badges proved difficult to do in the field. The primary investigator elected to finish the collection using the same method of putting the badge in the can that the field technician had used from the beginning. This decision resulted in a consistent systematic error for all measurements, but as long as the variance was high the comparative measures would still be useful.

Every day, the community technician downloaded data, recalibrated, and recharged the monitoring pumps. The technician removed, labeled, and placed the 3M passive badges in the freezer. Every day, new 3M badges were given to participants.

The passive badges targeted benzene, toluene, ethyl benzene and the xylenes and were evaluated by National Institute for Occupational Safety and Health protocol. The charcoal filters were extracted using 1 mL of CS_2 containing 5 ug/mL 4-bromofluorobenzene as the internal standard (ISTD). Extraction solvent was freshly prepared for each set of samples analyzed. We placed each charcoal pad inside a 2 mL amber vial, added 1 mL of the extraction solvent and closed the vials with Teflon lined caps. The pads were desorbed for 40 min in an ultrasonic water bath maintained within 15 to 18°C by adding small amounts of ice. After sonication, technicians withdrew the extract and transferred it to an amber autosampler vial. Working analytical standards in the range of 0.1 to 10 ug/mL were prepared using the solvent plus ISTD for dilution of commercial standard solutions. Technicians used a Varian 3800 Gas Chromatograph equipped with a Varian 2200 Ion Trap detector to analyze all extracts and standards. Separation was accomplished using an RTX-1 60 m x 0.25 mm id column with a 1 mm film thickness. Dr. John Kennish, professor of chemistry University of Alaska Anchorage, performed this work at the ASETS laboratory.

FEV1 and Breath Condensate Measurements

Each participant was expected to spend about one hour per day with the project and was paid a stipend for their time. Participants were grouped so only three participated at a time in order to distribute the work and provide rest periods for the single medical researcher in the community.

Measurements of FEV1 was obtained first as the participant was asked not to use bronchial dilators prior to the encounter. After a baseline FEV1, the participant was given two inhalations

of albuterol, a bronchial dilator. Five minutes post dilator, the technician measured FEV1 again to determine how much reversible bronchial constriction was present. Participants then exhaled into a plastic tube wrapped in an ice jacket. The ice jacket allowed moisture in the breath to condense and form breath condensate. Breathing into the breathing tube for 5-8 minutes generated 1-2 ml of condensate which was tested immediately for pH using a handheld pH meter. This simple apparatus is manufactured by Respiratory Research, Inc. The information was entered into a database on a laptop computer as collected.

Every day, the community research assistant recalibrated and recharged the monitoring pumps that had been used the previous day. The local research assistant sent specimens and health data to the PI on a weekly basis. The PI entered all of the information into a database at the Institute for Circumpolar Health Studies. The DPM cassettes were sent to DataChem in Salt Lake City. Badges were sent to Department of Chemistry at UAA for BETX analysis.

Appendix C - Ambient Monitoring Data Set