Development of an Exposure Model for Diesel Locomotive Emissions near the Alameda Corridor

FINAL REPORT

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Disclaimer

Abstract

The present investigation is part of a program of study at the Center for Energy and Environmental Research and Services (CEERS) at CSULB to assess the exposure risks of the particulate matter (PM) in the outdoor environment related to the seaport operations and goods movement. An approximation of $PM_{2.5}$ concentration was obtained for the diesel locomotive emissions near the Alameda corridor railroad using a TSI DustTrak aerosol monitor. Measurements were carried out at different distances from the railroad from -4.6 m to 90 m, where the distance of -4.6 m denotes the distance from the other side of the railroad. For all measurements, local wind speed and direction were obtained using a Young model 85000 2-axis anemometer. The investigations were performed on different days. At each monitoring location, extended measurements were carried out to assess the effects of different locomotives on the local PM concentration. Results indicate between10-15% increase in PM concentration from the passage of the diesel locomotives.

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Disclosure

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1.0. INTRODUCTION

More than 30 years of studies(Vedal (1997)) have shown significant adverse effects of ambient particulate matter (PM) on respiratory systems, especially in high risk population such as infants, young children and elderly. Coarse and fine particles have aerodynamic diameters of less than 10 and 2.5 microns, respectively, and ultra-fine particles have aerodynamic diameters of less than 0.1 micron. Fine and Ultra-fine particles constitute more than 80% of the PM numbers in an urban area (Morawska et al (1998b)) and they typically contain soot, acid condensates, sulphates and nitrates and other toxins and traces of metals.

Many studies (e.g.: Hitchins et al (2000), Zhue et al (2002), Sardar et al (2004), Wu et al (2005)) have been attempting to develop exposure risk models for these particles and their associations with gaseous pollutants such as carbon monoxide (CO), nitric oxide (NO), oxides of nitrogen (NOx) and ozone (O3). These studies show that dispersion and concentration of these pollutants are strongly dependant on local wind speed and direction and there are, in general, weak degrees of correlation between particle numbers and the gaseous concentrations. In addition, the concentrations of these pollutants are reduced at distances from the major roads where some of these studies were performed.

The Los Angles-Long Beach port is the busiest port in the United States, handling more than 43% of the total seaborne cargo. It is also responsible for nearly a quarter of diesel emissions in the region. Big rig trucks, diesel locomotives and mammoth container ships contribute significantly to the region’s air pollution with severe impact on local communities. Many schools are very close to the port traffic lines and railroad and are significantly affected by these emissions as well.

The objectives of the present investigation were to measure gaseous pollutants and particulate matter at different distances from the Alameda corridor railroad from passage of diesel locomotives, for development of exposure models for these emissions.

2.0. BACKGROUND

The structure of the diesel exhaust from a moving train without the cross wind and distortions by the surrounding structures is similar to the flow of a single jet in a cross flow. Experiments have shown that there are four known vortices for a single jet in a cross flow. Figure 1 shows these vortices. These are the jet shear layer and horseshoe vortices, the wake vortices and the counter rotating vortex pair (CVP). Beyond the initial region, the CVP is the dominant vortex structure, after the jet has tilted in the cross flow direction and is the main structure responsible for diffusion and mixing process downstream.

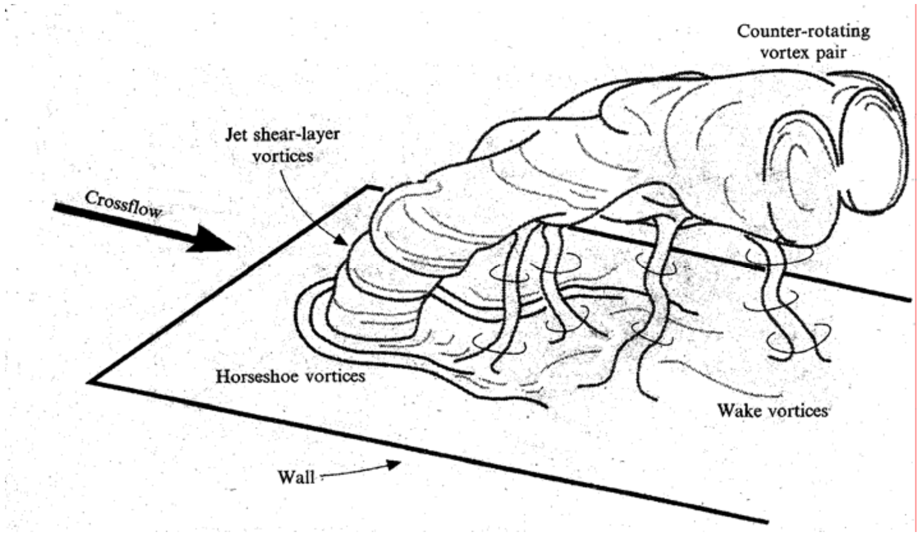

Figure 1. Vortical structure of a vertical jet in a cross flow (From Fric and Roshko [1994]).

The diesel exhaust trajectory is also affected by the density of the gas, the surface wind and the surrounding structures. Some particulates and pollutants within the diesel exhaust act as a passive scalar and their decay rate are influenced by shear strain imposed on their flow field. Previous studies by Rahai and LaRue (1992, 1993) on the impact of a non-uniform strain on decay rate of a passive scalar have shown that depending on the background wind condition, the decay rate is either stays the same or is reduced, as compared with the corresponding decay rate when the shear strain is not present. Thus it is essential that the surrounding and background conditions are taken into account when developing a model for the trajectory of diesel exhaust emissions from a moving train.

3.0. MEASUREENTS PROCEDURE AND TECHNIQUES

All measurements were carried out along the Anchorage road at and near the intersection of the Anchorage and the Henry Ford road, adjacent to the Badger Bridge in the city of Wilmington. The following pictures show the bridge and its vicinity. This location was selected after nearly six month of exploration for finding a convenient and safe location for placing measurement equipment and conducting measurement and monitoring activities which include active participations of our graduate students and technical support personnel. Adjacent to the Badger Bridge is the Camador Heim Bridge along the Terminal Island freeway, which is, the main route for the truck traffic, serving the ports of LA/LB. Both bridges are lifted for maritime traffic, except between 1-4 PM where priorities are given to the truck and train traffic. The bridges are manned 24 hours per day 7 days a week by the Pacific Harbor Line company. On the south side of the bridge is the ducking area for loading and unloading of cargo ships.

There are two railroad tracks, separated by approximately 3 m (10 ft). The east track which is closer to the Comador Heim Bridge and the west track which is adjacent to the Henry Ford Road, are nearly perpendicular to the Anchorage road. Except at X=-4.6 m, all measurements were carried out along the Ancholarge road. The locomotives operating along the Alameda Corridor railroad are mainly from three companies: Burlington Northern Santa Fe (BNSF), Pacific harbor Line (PHL), and Union Pacific (UP). Depending on the size of the cargo, between 1 to 4 locomotives are used. The following pictures show some of the locomotives during their operations along with their exhaust emissions.

The aerosol concentration was measured by a TSI DustTrak model 8520, which uses light scattering technology to determine mass concentration in real-time. A continuous stream draws aerosol sample into a section of a sensing chamber which is illuminated by a small laser beam light. Particles in the aerosol sample scatter light in all directions where some are collected and focused on a photodetector which converts the light into the voltage. The voltage is linearly proportional to the mass concentration of the aerosol. The scattered light depends upon the particle size. The smallest detectable particle for this unit is about 0.1 µm. The unit is supplied with three different inlet nozzles for different size particle measurements. For the present investigations, the 2.5 µm inlet nozzle is used. The time interval for collecting samples was set at either 1 or 5 seconds. The unit was placed in an environmental enclosure with rechargeable battery for continuous unattended sampling The aerosol sampling inlet is attached to the outside of the enclosure and is connected to unit inside via tubing. The unit can be operated without recharge between 8 hours to one month based on the sampling rate. For our measurements, initially a one second sampling rate was selected, but later the rate was increased to 5 second to allow for 24 hours measurement cycle.

Local wind speed and direction were measured using a Young model 05106 wind monitor-MA which can measure speed between 0-60 m/sec. and wind direction range of 0-360º for outputs of 0-5 VDC with an overall accuracy of ±1% of the full range. A portable ENERAC micro-emissions analyzer model 500 which is capable of measuring accurately the ambient temperature, stack temperature, oxygen, nitric oxide (0-2000 PPM), nitrogen dioxide (0-1000 PPM), carbon monoxide (0-2000 PPM), sulfur dioxide (0-2000 PPM) and stack draft was used for monitoring local concentration of pollutants from locomotive and truck traffics. The unit was run continuously and outputs were recorded using a Dell portable laptop. However, due to low level of pollutant concentrations, the unit was unable to produce useful results and thus these data are not included in this report.

The results presented in this report are from locations at approximately 4.6 m (15 ft) from the east track between the railroad and the Comador Heim Bridge and at 9.75 m (32 ft), 23 m (75 ft), 44.2 m (145 ft), 61 m (200 ft), and 91 m (300 ft) from the west track along the Anchorage road perpendicular to the railroad. At each location, between 8 hours to 24 hours of data was collected. Measurements were repeated on several occasions to ensure the accuracy of the data. A minimum passage of 10 locomotives was observed for each location and the type and the numbers of locomotives for each passage were recorded.

The following pictures show the aerosol and the wind monitoring units. As the pictures show, both units were mounted on a pair of tripods to allow for flexibility, mobility and relocation. In general, a maximum height of 8 ft was maintained for these units during operation.

4.0. RESULTS AND DISCUSSION

Figures 1-5 show variation of the aerosol concentration at different distances from the West railroad track. In order to capture the aerosol concentration from passage of the locomotives, a time window of between 1-3 minutes was assumed, which is the duration between the time the locomotives arrive near the Anchorage road and pass through. The maximum concentration taken within this time window was taken as the concentration from the passage of the locomotives. In addition, the background concentration was recorded as the maximum value obtained within 2 minutes before the locomotives arrive at the measured locations.

Train traffic was different on different days. Most trains arrived during early morning hours or in late afternoon. However, in general there was no regular schedule for the train traffic. In addition, depending on the cargo and operating company, the numbers of locomotives employed were different and thereby it was difficult to assess the effects of single locomotive on the local aerosol concentration.

The truck traffic was relatively continuous, except for stoppages due to the maritime traffic and lifting of the bridges.

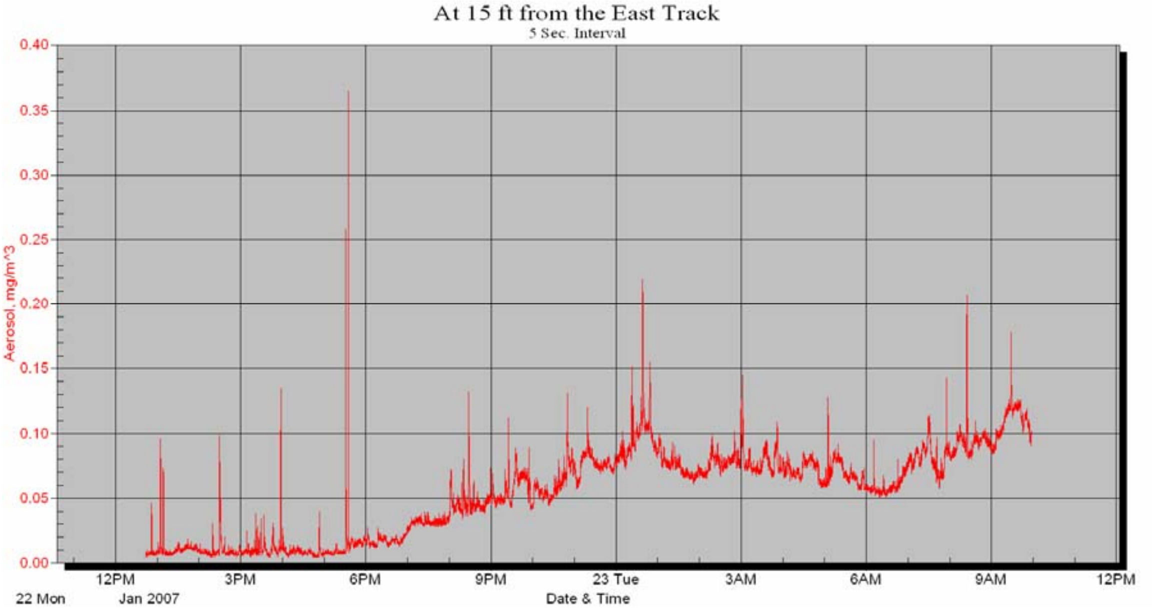

Figure 2. Variation of aerosol concentration at -4.6 m from the west track. Average wind speed and direction: 0-3 mph, NW.

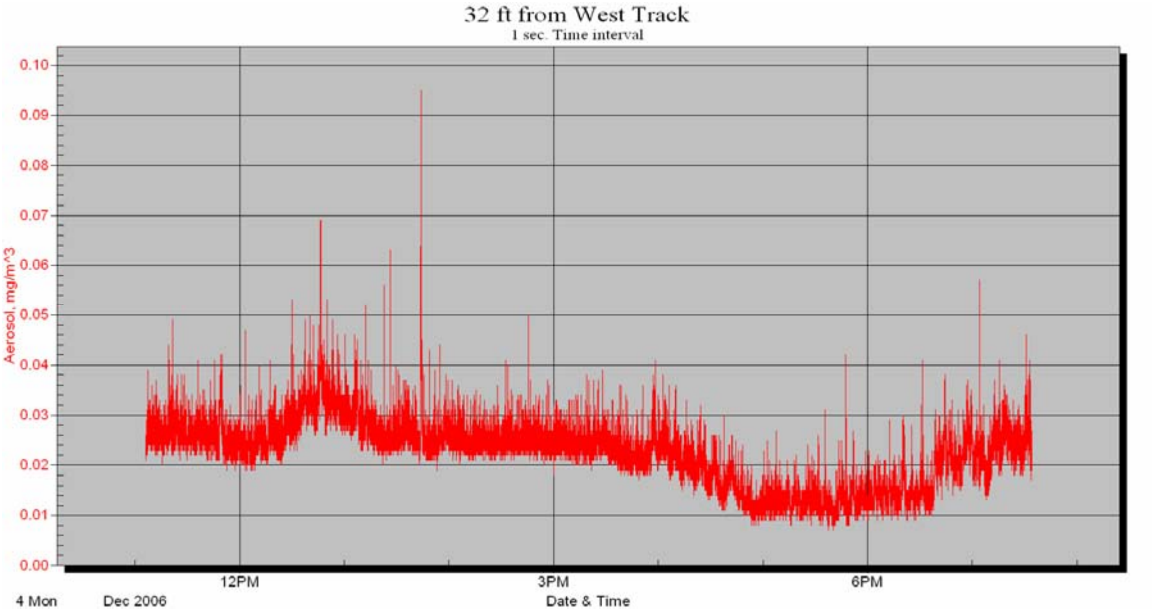

Figure3. Variation of aerosol concentration at 9.75 m from the West track. Average wind speed and direction: 0-7 mph, NW.

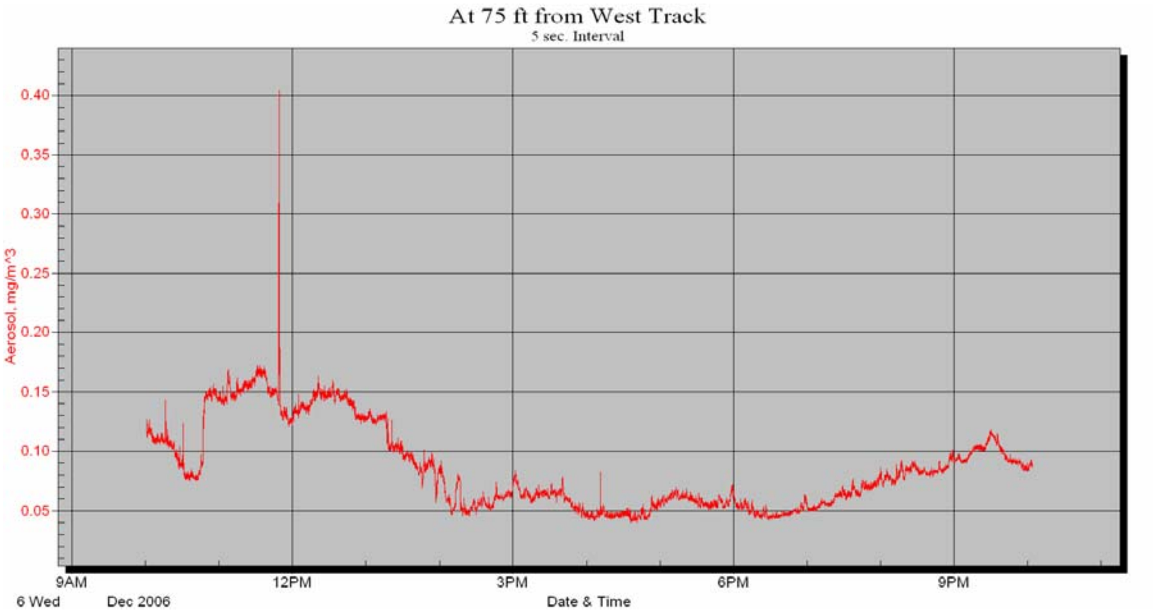

Figure 4. Variation of aerosol concentration at 23 m from the West track. Average wind speed and direction, 0-3 mph, NNW.

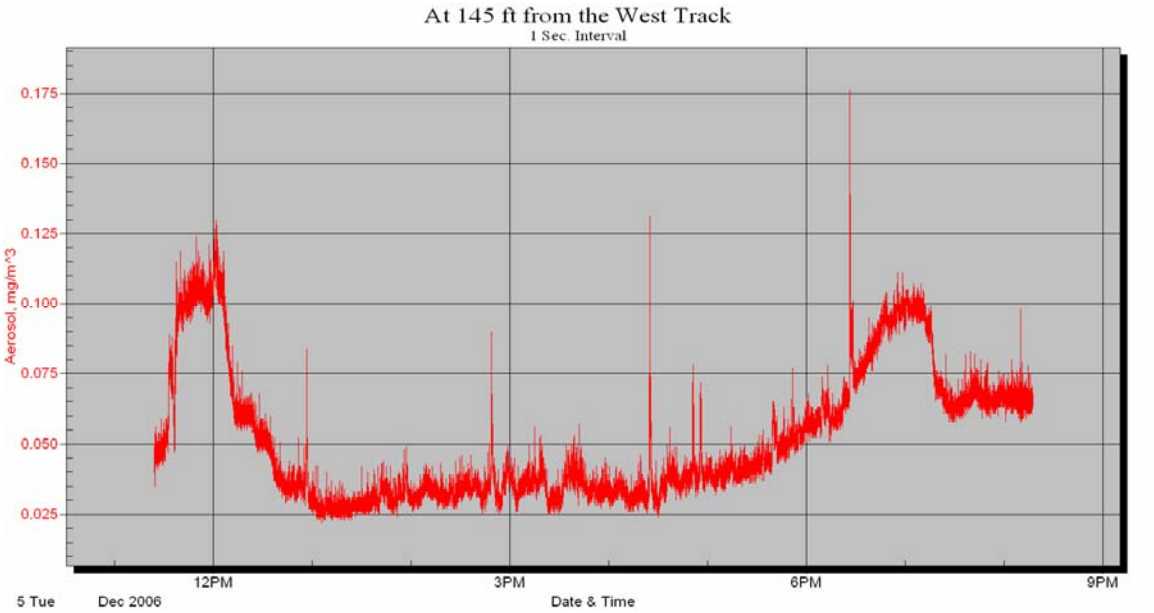

Figure 5. Variation of aerosol concentration at 44.2 m from the West track. Average wind speed and direction, 0-2 mph, SW.

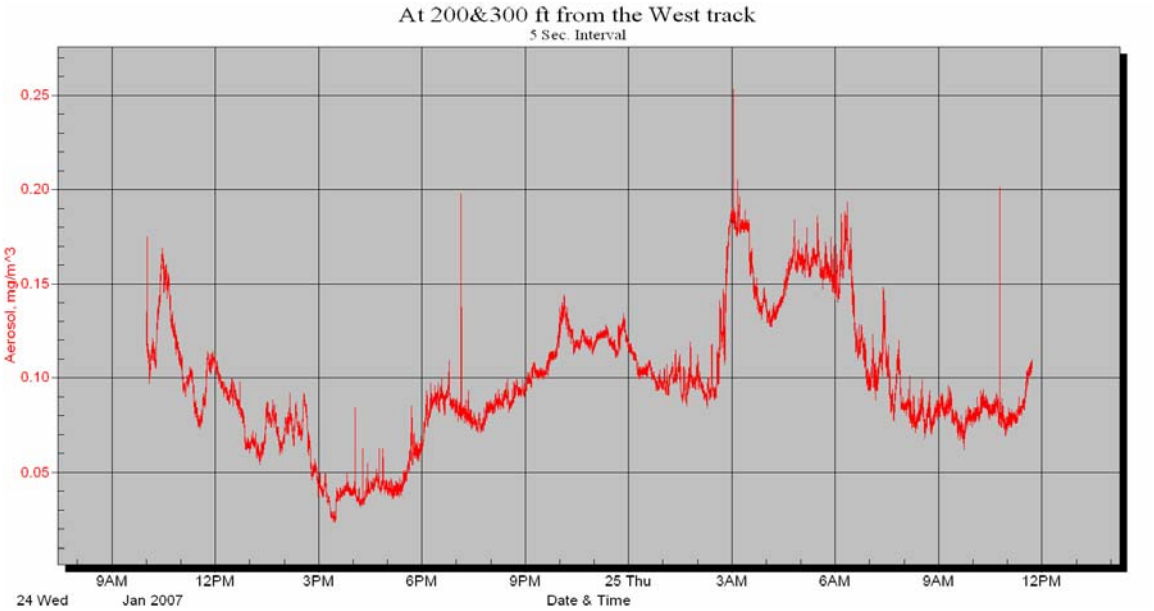

Figure 6. Variation of aerosol concentration at 61 m and 91.5 from the West track. At 1:12 PM the monitors were moved from the 200 ft distance to the 300 ft distance. Average wind speed and direction: 0-3 mph, West.

Figures 6-9 show individual and averaged variations of the aerosol concentration from the passage of the diesel locomotives and similar results for the background concentration. As the results indicate, the initial concentration at x=-4.6 m is low, but it increases to relatively high values at X = 23 m and X= 60 m, before it decreases to smaller values at the furthest downstream location. The data at each X station is due to passage of different locomotives. The fluctuation in the aerosol concentration is due to small variation in the wind speed and mostly due to changes in the background pollution due to truck traffic and truck idling. The wind speed was generally very low during the measurements and occasional gusts during early afternoon were mostly coincided with limited train operation.

During the maritime traffic, both the Badger bridge and the Comador Heim Bridge were lifted which halted both the train and truck traffics. While there was no train near the bridge during these times, there were lines of trucks idling over the bridge and beyond, waiting for the bridge to open. The trucks idling resulted in 20% to 100% increase in aerosol concentration. The following pictures show truck stoppages due to the lifting of the Comador Heim bridge.

All truck idling events and their proximity to the passage of the locomotives were recorded during the field measurements.

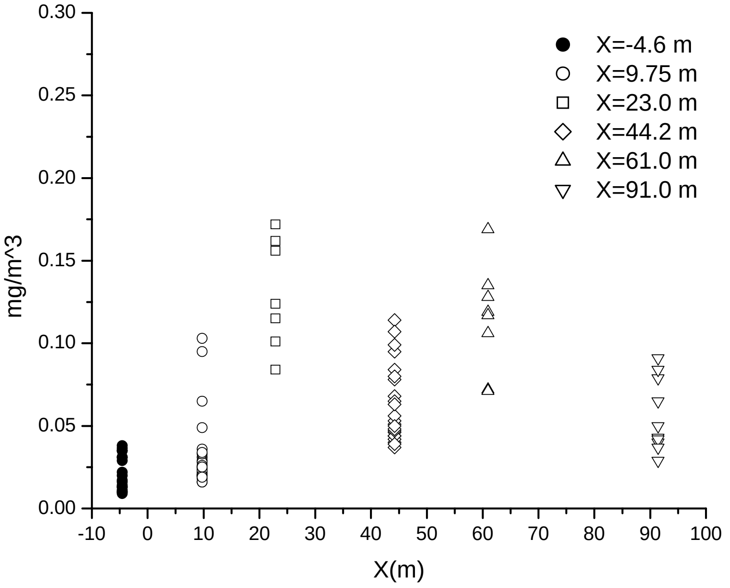

Figure 7. Axial variation of aerosol concentration from passage of the trains.

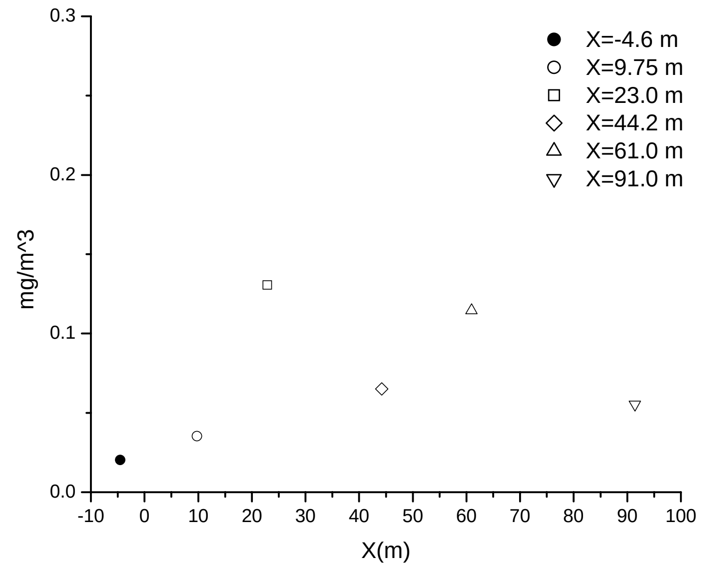

Figure 8. Axial variation of averaged aerosol concentration from passage of the trains.

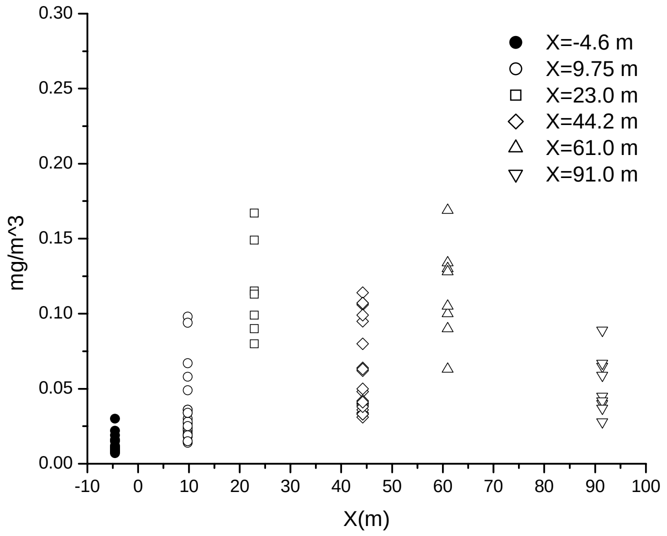

Figure 9. Axial variation of background aerosol concentration.

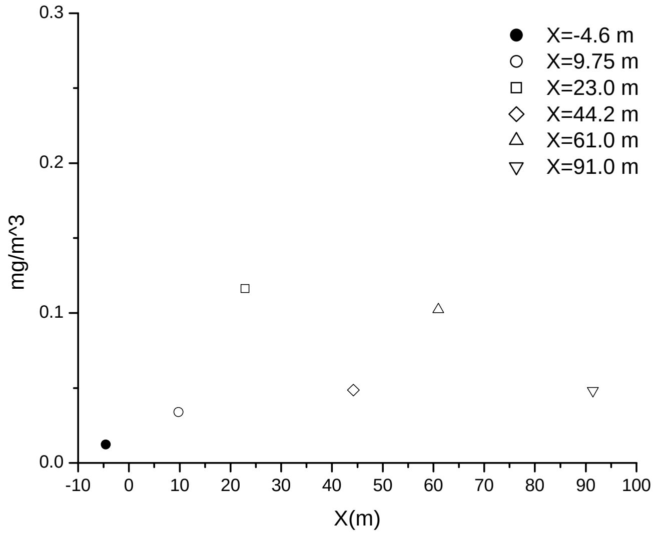

Figure 10. Axial variation of averaged background aerosol concentration.

Maritime traffic was high when measurements were performed at X=23 m. There were five truck stoppages, resulting in truck idling times of 2 to 7 minutes for each stoppage. In addition, there were proximity between the start of the truck traffic and the passage of the locomotives after each stoppage, and thus, the measured aerosol concentrations were relatively high due to the increased background aerosol concentration.

Figure 10 shows variation of the normalized aerosol concentration with distance. The normalized concentration was obtained by dividing the average concentration from the passage of the locomotives at each location with the corresponding average background concentration. As the results indicate, the concentration is more than 60% of the background concentration at X=-4.6 m, which is the location between the railroad tracks and the Comador Heim Bridge. The concentration decreases significantly at X=9.75 m and then increases to approximately 125% of the background concentration at X = 44.2 m. The concentration decreases to values between 12 to 15% above the background concentration at further downstream stations. Overall, excluding the initial station (X=-4.6 m), the average increase in PM concentration near the railroad due to the passage of the locomotives is between 12-15%.

One of the initial objectives of the project was to assess the impact of wind and updraft on the diffusion of the pollutions concentration. Updraft is formed when the interior portions of the region is heated by the sun and heated air near the ground is moved upward and relatively cooler air over the ocean is drawn inland. However, except for occasional gusts, the wind speed and direction at the measurement locations during the passage of the locomotives were not significant and did not affect the diffusion process. Previous investigation (Hitchins et al. (2000)) on the impacts of wind speed and direction on diffusion of pollutants from vehicle emissions near a major road have shown that beyond 15 m from the road, the total number concentration is insensitive to the wind direction, when wind is blowing toward or away from the sampling points. Assuming similar conclusion, the present results are independent of the wind direction and indicate that beyond the initial two stations, the PM concentration is initially high and decreases with distances away from the railroad. For the three measurement locations of 44.2, 61, and 91 m, the linear fit to the normalized data produces a slope of -0.094, and an intercept of 1.4. Studies by Su and Mungal (2004) on the decay of scalar concentration from jets in cross flow have shown that for both flush and elevated nozzles, the normalized scalar decay has a linear region with an approximate slope of -0.1 which is near the corresponding value for the present results. Thus, it can be hypothesized that for X> 10 m, the decay of the normalized PM concentration with distance is approximately proportional to -0.1.

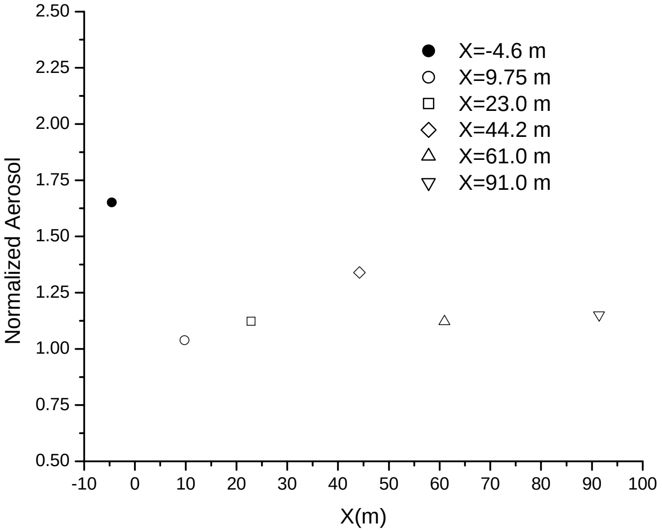

Figure 11. Axial variation of normalized aerosol concentration.

5.0. CONCLUSIONS AND RECOMMENDATIONS

Measurements of the wind speed and direction and aerosol concentration from the passage of diesel locomotives were performed along a road perpendicular to the Alameda corridor railroad, using a Young model 05106 wind monitor system and a TSI DustTrak model 8520, respectively. Measurements were carried out on different days and at distances from the railroad track ranging from -4.6 m to 91 m. The wind speed during the measurements was low to calm and did not have any significant effect on diffusion of the concentration. Considering the background concentration, beyond the distance of less than 10 m from the railroad, results indicate an average of 12 to 15 % increase in aerosol concentration due to the passage of the diesel locomotives. The available sensor for gaseous concentration was not sensitive enough to detect variation of gaseous pollutants and thus, correlations between other pollutions and the aerosol concentration were not found. Further study for measurements of other gaseous pollutions at the same locations and their relation to the aerosol concentration are recommended.

With the current measurement techniques, it was not possible to resolve information about the sub-micron particles and their fractions. This requires a differential mobility analyzer which was not acquired due to the limited funding available for this project.

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