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Implications of changing PM10 Air Quality Standards on Pacific Northwest communities affected by windblown dust☆

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ABSTRACT

The US Environmental Protection Agency (EPA) is currently reviewing the National Ambient Air Quality Standards (NAAQS) for Particulate Matter. EPA is considering the recommendation to change both the form and level of the PM10 (particulate matter ≤10 μm in diameter) Standard. The implication of the recommended NAAQS for PM10 on air quality is explored in this study. Daily observations of PM10 were made at Kennewick and Spokane, WA from 2000 through 2010. The number of violations of the PM10 Standard was determined for both the current (not to exceed 150 μg m^{-3} on more than one day per year) and recommended (not to exceed 65 or 85 μg m^{-3} based upon the 98th percentile) Standards. The current PM10 Standard has only been violated at Kennewick. Under the recommended PM10 Standards, Kennewick would have violated the Standard at both the 65 and 85 μg m^{-3} levels while Spokane would have violated the Standard at only the 65 μg m^{-3} level. The results of this study suggest that the recommended NAAQS for PM10 using a level of 85 μg m^{-3} will tend to result in fewer violations of the Standard and using a level of 65 μg m^{-3} will tend to result in more violations of the Standard in the Inland Pacific Northwest. The Exceptional Event Rule and research on management practices to control the emission of fugitive dust will continue to be important strategies for achieving compliance with PM10 Air Quality Standards in the Inland Pacific Northwest.

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1. Introduction

Air Quality Standards have been adopted by many countries around the world to protect public health and welfare against the adverse effects of air pollution. In fact, member countries of the World Health Organization have adopted a constitution that sets guidelines on air pollutants. The Organization, which has representation from nearly 200 countries, recommends daily PM10 concentrations not exceed 50 μg m^{-3} (World Health Organization, 2005). Many countries, however, have chosen to set Air Quality Standards that are more relaxed or more stringent than this Standard. Air Quality Standards are generally created or revised according to national policy and scientific information that demonstrates a plausible association between health-related illnesses and exposure to pollutants. The European Union, for example, has set a daily PM10 Standard of 50 μg m^{-3} that should not be exceeded more than 35 days per year (European Commission, 2011). Likewise, the United States has set a daily PM10 Standard of 150 μg m^{-3} that should not be exceeded more than one day per year averaged over three years.

In 1971, the Clean Air Act required the EPA to establish NAAQS for particulate matter (US Office of the Federal Register, 1971). Particulate matter included total suspended particles up to a nominal diameter of about 45 μm. The level and form of the primary Standard set forth for total suspended particles included a daily concentration not to exceed 260 μg m^{-3} more than one day per year and an annual mean concentration not to exceed 75 μg m^{-3}. In 1987, the particulate matter Standard was revised to protect humans against inhaling particles that could be deposited in the respiratory tract (US Office of the Federal Register, 1987). Particles regulated were ≤10 μm in aerodynamic diameter (PM10). The level and form of the Standard established for PM10 included a daily concentration of 150 μg m^{-3} with no more than one exceedance per year and an annual concentration not to exceed 50 μg m^{-3} averaged over three years. In 1997, the daily PM10 Standard was revised (US Office of the Federal Register, 1997) based upon the 99th percentile of the daily concentrations. The Standard was later revoked by the US Supreme Court. In 2006, the PM10 Standard was revised to exclude an annual PM10 Standard.

Abbreviations: PM10, particulate matter ≤10 μm in diameter; EPA, US Environmental Protection Agency; NAAQS, National Ambient Air Quality Standards.

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Several locations within the Inland Pacific Northwest United States failed to achieve NAAQS for PM10 in the late 1980's and early 1990's (Department of Ecology, 2003). Failure to achieve PM10 Standards is largely associated with dust storms that develop as low pressure systems pass through the region. These low pressure systems typically result in high winds capable of eroding soil during spring and autumn across the region. Agricultural lands located in the low precipitation zone (<300 mm of annual precipitation) are the primary source of PM10 (Papendick, 2004). These lands are particularly vulnerable to wind erosion during the fallow phase of the conventional winter wheat–summer fallow rotation. Winter wheat is grown every other year due to the poor temporal distribution of and inadequate amount of annual precipitation. During the fallow year, the land is periodically cultivated and the soil surface remains partially or totally denuded for much of the 14-month fallow period. Agricultural soils in the low precipitation zone are particularly vulnerable to erosion due to the high silt and fine sand content, low organic matter content, and poor aggregation. Although daily PM10 concentrations may exceed the PM10 Air Quality Standard during high wind events in the region, exceedance of the Standard does not necessarily violate the Clean Air Act due to the possibility for exclusion of these high concentrations in accordance with the Exceptional Event Rule (US Environmental Protection Agency, 1996).

In 2004, the EPA had proposed to regulate PM_{coarse} (US Environmental Protection Agency, 2004). The proposed Air Quality Standard for PM_{coarse} considered particulate matter with a diameter of 2.5–10 μm, with PM_{coarse} being assessed as the difference between simultaneous PM10 and PM2.5 (particulate matter ≤2.5 μm in diameter) observations. The level and form of the proposed standard was not to exceed a 24-h concentration of 70 μg m^{-3} based upon the 98th percentile of 24-h concentrations averaged over 3 years. Sharratt and Lauer (2006) examined the impact of imposing this new Air Quality Standard on exceedances of the Standard at Kennewick, WA. This community was chosen for analysis because Kennewick had a history of exceeding previous PM10 Air Quality Standards due to windblown dust. In addition, this community was expected to exceed the proposed PM_{coarse} Air Quality Standard because of its proximity to the Horse Heaven Hills which is a major source of windblown crustal and geologic material (Schillinger and Young, 2004) that comprises a large fraction of PM_{coarse} (Chow et al., 1994). Sharratt and Lauer (2006) found that the proposed PM_{coarse} Air Quality Standard would result in 120% more exceedances than previously recorded at Kennewick. Since PM2.5 constituted only 4–7% of PM10 during high winds, their finding is particularly relevant to this study because the form and level of the PM_{coarse} Standard is similar to the form and level of PM10 Standard now being considered by EPA. They also reported that PM10 concentrations <75 μg m^{-3} were influenced by local sources (e.g. industrial activities) while PM10 concentrations >75 μg m^{-3} were influenced by synoptic weather systems. Their data also suggested an increase in the number of exceedances of the Air Quality Standard as the level of the PM10 Standard is reduced from the current daily concentration of 150 μg m^{-3}.

The EPA is considering the recommendation to revise both the level and form of the PM10 Air Quality Standard to protect US citizens from the adverse health effects of exposure to PM10. As a result of concern by the agricultural community in further regulating PM10, the EPA has met with communities around the United States. The impact of the level and form of the PM10 Standard being recommended by the National Center for Environmental Assessment (US Office of the Federal Register, 2009) on violations of the Standard is not known for the Inland Pacific Northwest. Violation of the recommended PM10 Standard is expected based upon the high frequency of dust storms and the large contribution of crustal material to fugitive dust in the region. Therefore, the aim of this paper was to explore the implication of the recommended PM10 Air Quality Standard on compliance with the Standard in the Inland Pacific Northwest.

2. Materials and methods

The Inland Pacific Northwest is confined by the Okanagan Highlands to the north, the Cascade Mountains to the west, the Blue Mountains to the south, and the Bitterroot Mountains to the east. This region has a diversity of agricultural crops owing to the variation in precipitation. Annual precipitation ranges from about 100 to 600 mm across the region (Fig. 1). The low precipitation zone (annual precipitation <300 mm) is of most concern with regard to windblown dust and its affect on air quality. Within the low precipitation zone, both irrigated and dryland soils are exposed to high winds that are predominately from the southwest and typically the strongest during spring and autumn.

The EPA currently measures PM10 concentrations at seven locations in the Inland Pacific Northwest. These locations include Pendleton, OR and Burbank, Clarkston, Colville, Kennewick, Spokane, and Yakima, WA. The Burbank, Spokane and Yakima monitoring locations were originally designated by EPA as nonattainment for PM10, but have since been classified as maintenance areas due to achieving compliance with PM10 Standards by adopting control practices. The Kennewick site was designated as unclassified because the community lacked industrial or population sources of PM10 to cause violation of the PM10 Standard. Kennewick has an annual precipitation of 200 mm and is located immediately downwind (northeast) from the Horse Heaven Hills. The Horse Heaven Hills is the driest rainfed wheat producing region in the world and is a major source of windblown dust (Schillinger and Young, 2004). Spokane has an annual precipitation of 420 mm and is located in the intermediate precipitation zone (300–450 mm of annual precipitation) of the Inland Pacific Northwest. Air quality of the community is compromised as windblown dust is carried downwind from agricultural lands within the low precipitation zone. Spokane lies less than 100 km downwind of the low precipitation zone where agricultural lands are managed in a conventional wheat–fallow rotation.

Data collected at the Kennewick and Spokane locations (Fig. 1) were used to assess the impact of the level and form of the recommended NAAQS for PM10 on air quality. These locations were chosen due to a history of exceedances of the PM10 Air Quality Standard, absence of major industry in the immediate area, proximity to source of windblown dust, and detailed daily records of PM10 concentration. The Kennewick and Spokane monitoring locations are part of the State and Local Air Monitoring Stations (SLAMS) network used for official air quality monitoring in the state of Washington. Daily PM10 observations were acquired at both locations from 2000 through 2010. These years provided sufficient data to compare compliance to current and recommended PM10 Air Quality Standards as well as recent data that reflect the impact of current agricultural practices on air quality within the Inland Pacific Northwest. Daily PM10 concentrations were measured using federal reference method filter-based samplers or federal equivalent method Tapered Element Oscillating Microbalances (TEOM). The TEOM was used in the event that the federal reference method filter-based sampler was being serviced or inoperative. Observations were available for about 88–100% of days across all years at both locations except 2009 (51%) and 2010 (70%) at Spokane. Periodic site maintenance or instrument failure resulted in missing daily observations.

Daily PM10 concentrations were analyzed for compliance to current and recommended PM10 Air Quality Standards. The level and

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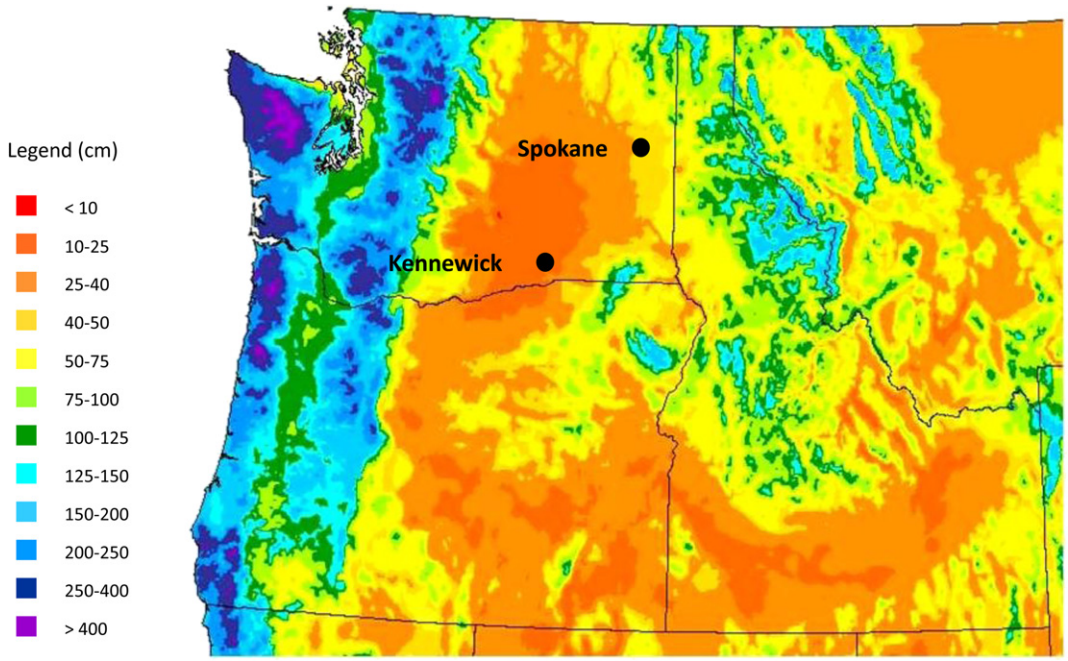

Fig. 1. Annual precipitation isopleths across the Pacific Northwest. Kennewick, WA is located within the low precipitation zone (<300 mm annual precipitation) and Spokane, WA is located within the intermediate precipitation zone (300–450 mm annual precipitation).

form of the current PM10 Standard requires PM10 concentrations not exceed 150 μg m^{-3} on more than one day per year averaged over three consecutive years. Thus, the Standard is violated when the daily PM10 concentration exceeds 150 μg m^{-3} on two or more days per year averaged over three consecutive years. The level and form of the recommended PM10 Air Quality Standard requires the daily PM10 concentration not exceed 65–85 μg m^{-3} based upon averaging over three consecutive years the 98th percentile of observations within each year. The 98th percentile allows exclusion of 2% of the daily observations taken within each year. The Standard would then be violated if the 98th percentile of daily PM10 concentrations in a year averaged over three years exceeded 65–85 μg m^{-3}.

3. Results and discussion

The highest daily PM10 concentration observed from 2000 through 2010 at Kennewick was 1438 μg m^{-3} on October 28, 2003 and at Spokane was 268 μg m^{-3} on September 25, 2001.These PM10 concentrations were the second and ninth highest since observations began at Kennewick in 1987 and Spokane in 1986. Both concentrations exceeded the level of the current PM10 Standard of 150 μg m^{-3} d^{-1} and were caused by windblown dust. These PM10 concentrations would qualify for exclusion under the Exceptional Events Rule in determining compliance with current PM10 Standards. Daily concentrations in excess of 150 μg m^{-3} were observed in nine of the 11 years at Kennewick and four of the 11 years at Spokane. In total, there were 20 exceedances of the level of the current PM10 Standard at Kennewick and four exceedances of the Standard at Spokane over the 11 years of this study. All but two exceedances of the current PM10 Standard, both of which occurred at Kennewick, were attributed to windblown dust.

The cumulative frequency distribution of days with specific ranges of PM10 concentration at Kennewick and Spokane is illustrated in Fig. 2. Both locations exhibit similar distribution characteristics with a rapid decline in the number of days with higher daily PM10 concentrations. The decline was exponential as daily concentrations increased over the range of about 20–50 μg m^{-3}. In fact, the best fit of an exponential function to the data in Fig. 2 was observed between daily PM10 concentrations of 20 and 45 μg m^{-3} ($R^2 = 0.9996$) at Kennewick and between PM10 concentrations of 20 and 55 μg m^{-3} ($R^2 = 0.9992$) at Spokane. Only 1.0 and 0.5% of all days at Kennewick and Spokane, respectively, had daily PM10 concentrations >100 μg m^{-3}. Days with a daily concentration of 10–15 μg m^{-3} were most commonly observed at Kennewick (22% of all days had PM10 concentrations in this range) and at Spokane (16% of all days). Despite similarities in the cumulative frequency distribution at Kennewick and Spokane, differences are also apparent in the frequency distributions. Most apparent was the frequency of daily PM10 concentrations above 70 μg m^{-3} being greater at Kennewick than at Spokane and the frequency of daily concentrations below 70 μg m^{-3} being greater at Spokane. This suggests that there were more days with very high PM10 concentrations at Kennewick than at Spokane and more days with somewhat lower PM10 concentrations at Spokane than at Kennewick. In examining the data, there were more days with daily concentrations above 110 μg m^{-3} at Kennewick than at Spokane while there were more days with daily concentrations between 20 and 110 μg m^{-3} at Spokane than at Kennewick. The differences in the frequency distribution above and below a daily PM10 concentration of 70 μg m^{-3} between Kennewick and Spokane suggests that PM10 concentrations below and above 70 μg m^{-3} may be influenced by different sources or transport processes at Kennewick and Spokane. Sharratt and Lauer (2006) suggested that daily PM10 concentrations below 75 μg m^{-3} were affected by local sources (e.g. industrial activities) while above 75 μg m^{-3} were influenced by large scale processes (e.g. dust storms). A similar conclusion could be drawn in this study that daily PM10 concentrations at Kennewick are influenced more by large scale processes than at Spokane and that daily PM10 concentrations at Spokane are influenced more by local sources than at Kennewick. PM10 concentrations at Kennewick may be influenced by regional scale processes due to the proximity of the location to highly-erodible agricultural lands while concentrations at Spokane may be influenced by local rather than distant sources due to the location being

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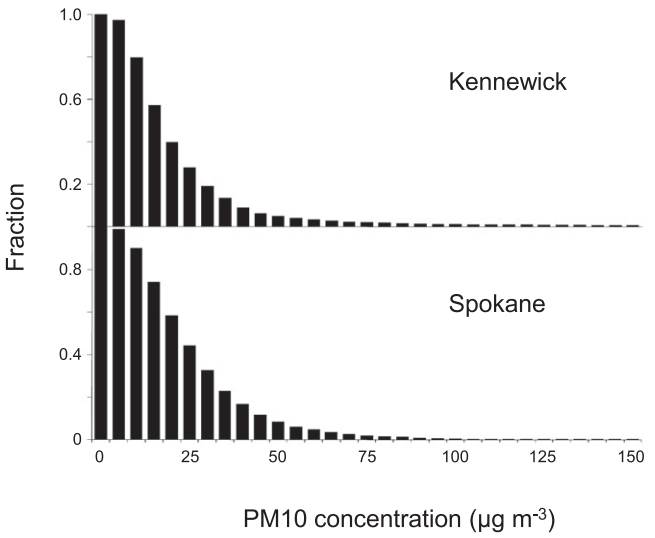

Fig. 2. Frequency distribution of daily PM10 concentrations measured at Kennewick and Spokane, WA from 2000 through 2010.

some distance from the highly-erodible agricultural lands. Identification of sources of PM10 affecting air quality in these two communities requires further research.

The number of days with PM10 concentrations that exceeded levels of the current and recommended PM10 Standard is indicated in Fig. 3. The levels of the PM10 Standard portrayed in Fig. 3 are 150 μg m^{-3}, which is designated in the current Standard, and 65 and 85 μg m^{-3}, which is the range suggested for the recommended Standard. The number of days that exceed the level of the PM10 Standard increased as the level of the Standard decreased from 150 to 85 to 65 μg m^{-3}. As previously noted, the level of the current Standard (150 μg m^{-3}) was exceeded on 20 days at Kennewick and on four days at Spokane over the 11 years of this study. Likewise, the number of days that exceeded a daily PM10 concentration of 85 μg m^{-3} was 57 days at Kennewick and 45 days at Spokane while the number of days that exceeded a daily PM10 concentration of 65 μg m^{-3} was 102 days at Kennewick and 129 days at Spokane. The current PM10 Standard is violated when PM10 concentrations exceed 150 μg m^{-3} on more than one day per year averaged over three consecutive years. Over the period of this study, the level and form of the current PM10 Standard was violated 78% of years (seven out of nine years) at Kennewick and not violated at Spokane. Thus, excluding high PM10 concentrations under the Exceptional Events Rule is important in complying with current PM10 Standards at Kennewick, but not at Spokane.

The current and recommended PM10 Standards differ in both the level and form of the Standard. While the level of the recommended PM10 Standard (65 or 85 μg m^{-3}) is nearly half of the current Standard (150 μg m^{-3}), the form of the current Standard requires averaging the number of exceedances while the form of the recommended Standard requires averaging the 98th percentile of PM10 concentrations. The level and form of the recommended PM10 Air Quality Standard requires the daily PM10 concentration not exceed 65–85 μg m^{-3} based upon averaging over three consecutive years the 98th percentile of observations within each year. The 98th percentile of the daily PM10 concentration is illustrated in Fig. 4 for each year. The 98th percentile of observations taken each day of the year is the eighth highest daily PM10 concentration taken over that year. A decline in the 98th percentile is apparent with time at both Kennewick and Spokane. This corresponds with a decline in the number of days with PM10 concentrations greater than 150, 85, and 65 μg m^{-3} (Fig. 3). Violation of the recommended PM10 Standard at a level of 85 μg m^{-3} occurred in 22% of years (two out of nine years) at Kennewick and did not occur at Spokane. Violation of the recommended Standard at a level of 65 μg m^{-3} occurred in 78% of years (seven out of nine years) at Kennewick and Spokane.

Although communities in the Inland Pacific Northwest have exceeded the level of the current NAAQS for PM10, compliance with the Standard has been achieved through the Exceptional Event Rule. This Rule allows communities such as Kennewick and Spokane in the United States to exclude exceedances of the Standard caused by exceptional or natural events. Thus, exceptional events such as volcanic eruptions or high winds that cause high daily PM10 concentrations can be excluded from computations that

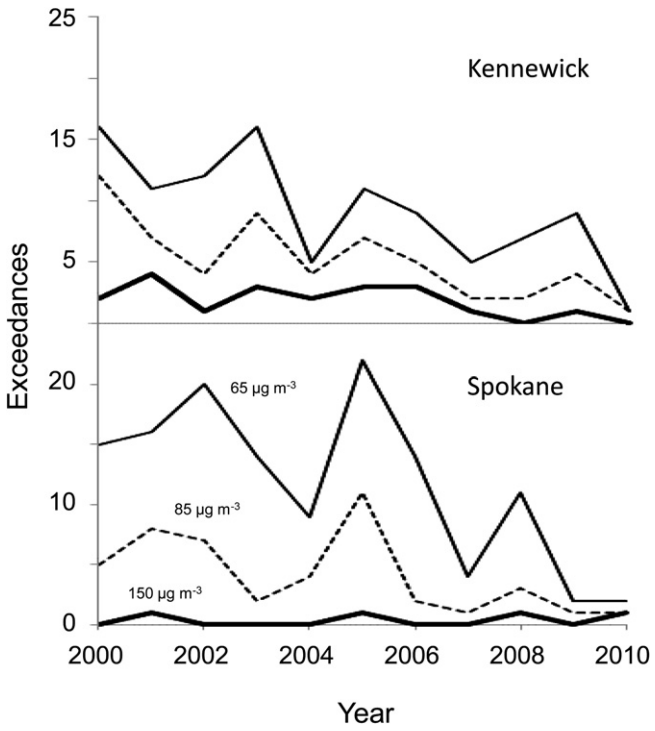

Fig. 3. Number of days that the daily PM10 concentration exceeded 150, 85, and 65 μg m^{-3} at Kennewick and Spokane, WA from 2000 through 2010.

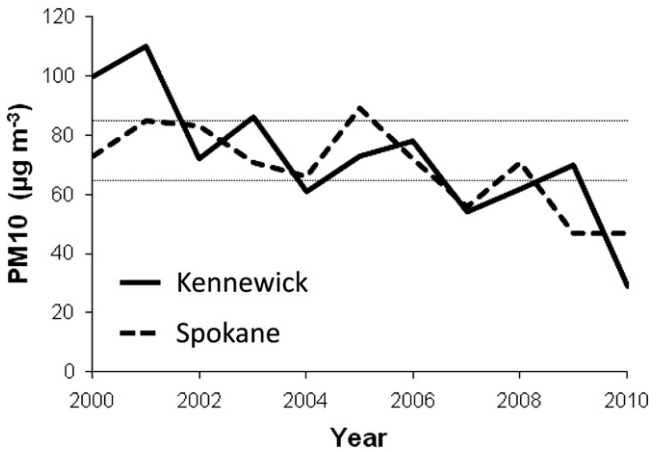

Fig. 4. The 98th percentile of daily PM10 concentrations observed at Kennewick and Spokane, WA from 2000 through 2010. The horizontal lines depict a PM10 concentration of 65 and 85 μg m^{-3}.

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determine compliance with the form of the Standard. Communities must not only demonstrate a linkage between an exceedance and the exceptional event, but must further demonstrate that best management practices are being implemented to minimize future exceedances caused by the exceptional event. Since high winds will continue to plague the Inland Pacific Northwest, the Exceptional Event Rule will continue to be an important policy in achieving compliance with future NAAQS Standards for PM10. In addition, continued adoption and research of best management practices for agricultural lands in the predominately wheat–fallow region of the Inland Northwest will be important in achieving compliance with PM10 Standards.

4. Conclusions

The agricultural community in the western United States is concerned about new PM10 Air Quality Standards being recommended to the EPA. The concern is particularly acute in the Inland Pacific Northwest where high winds have historically resulted in violation of PM10 Standards. Windblown dust originating from agricultural land is the primary source of PM10 that cause exceedance of the PM10 Standard. The EPA is considering a recommendation to change both the level and form of the current PM10 Air Quality Standard. While the level of the Standard may be reduced from 150 to between 85 and 65 $\mu g\ m^{-3}$, the form of the Standard may also be modified from averaging the number of exceedances of the level to averaging the 98th percentile of PM10 concentrations. The results of this study suggest that the recommended PM10 Standard with a level of daily PM10 concentrations not to exceed 85 $\mu g\ m^{-3}$ could result in no additional or fewer violations of the Standard while adopting a PM10 Standard with a level of daily PM10 concentration not to exceed 65 $\mu g\ m^{-3}$ could result in no additional or more violations of the PM10 Air Quality Standard in the Inland Pacific Northwest. The impact of adopting the recommended Standards on communities in the inland Pacific Northwest may depend upon the location of these communities in proximity to the agricultural lands that are the source of PM10.

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