United States Department of Agriculture

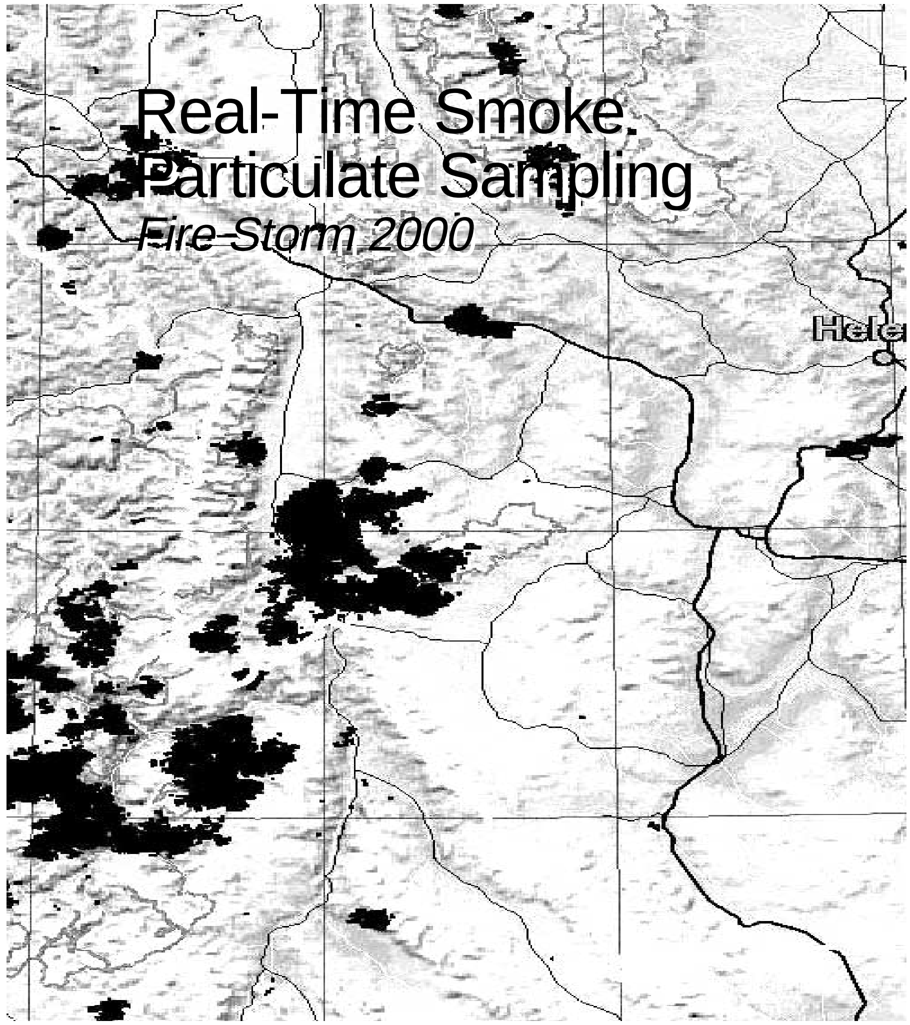
Forest Service

Technology & Development Program

2500 Watershed
October 2001
0125-2832-MTDC

Real-Time Smoke Particulate Sampling

Fire-Storm 2000



Andy Trent
Project Leader

Mary Ann Davies
Project Leader

Richard Karsky
Program Leader

Rich Fisher
Air Program Manager, Washington Office

USDA Forest Service
Technology and Development Program
Missoula, MT

9E92F52—$PM_{2.5}$ Air Sampler

October 2001

Table of Contents

Introduction

During the summer of 2000, extremely dry, hot conditions resulted in large natural wildfires throughout western Montana and Idaho. Area residents called the fire season Fire Storm 2000. Massive amounts of smoke settled in the valleys around western Montana and Idaho. The U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center (MTDC) deployed and evaluated real-time, particulate monitoring instruments to measure the smoke particulate concentrations. The center maintained two sets of real-time instruments, one in Missoula, MT, and one in Hamilton, MT. A U.S. Environmental Protection Agency (EPA) Federal Reference Method (FRM) $PM_{2.5}$ sampler was collocated with the instruments at each location. The main goal of the instrument collocation study during Fire Storm 2000 was to determine the accuracy of the real-time instruments when measuring smoke particulate concentrations from natural wildfires.

Airborne particulates, especially particles smaller than 2.5 microns (μm) in diameter ($PM_{2.5}$), pose potential health, visibility, safety, and nuisance problems at certain concentrations. Smoke particles, whether from prescribed burning or natural wildfire, are generally smaller than 2.5 μm and pose a potential health threat to individuals, especially persons with respiratory problems. Small particles are also the main reason smoke reduces visibility. The EPA has proposed annual and 24-h average $PM_{2.5}$ standards to protect human health. Regional haze regulations to improve visibility also target fine particles.

The center has been evaluating commercially available optical instruments that estimate particulate concentration in real time. These instruments can provide land managers and air quality specialists with valuable real-time airborne particulate concentration information during managed forest and rangeland burning. Managing smoke to protect human health and public welfare is an essential part of each prescribed burn plan. The proper use of ambient air quality monitoring can help ensure that prescribed burning complies with State and Federal air-quality laws and regulations while satisfying land management objectives.

The real-time particulate monitoring instruments can also provide local and State health department personnel, wildfire safety personnel, and communities with important particulate concentration information during times of severe wildland fires. Many rural communities do not have instruments to assess particulate concentrations. Communities can rely on visual techniques to estimate particulate concentrations, but these techniques are subjective and less accurate. Real-time instruments could provide community officials with more timely information to issue air quality stage alerts designed to protect local area residents.

The center has published two reports (figure 1), *Laboratory Evaluation of Two Optical Instruments for Real-Time*

Figure 1—Two reports (9925-2806-MTDC and 0025-2860-MTDC) detail the evaluation of several real-time particulate monitors in a laboratory and field setting.

Part 1 of 2

Particulate Monitoring of Smoke (9925-2806-MTDC) and *Evaluation of Optical Instruments for Real-Time Continuous Monitoring of Smoke Particulates* (0025-2860-MTDC). These reports provide details on real-time instrument evaluations in laboratory and field situations. Filter-based, direct mass measurements, specified by the EPA as reference or equivalent methods, are the standard techniques for determining particulate mass concentrations. Results from gravimetric samplers were used as the assumed actual representative particulate concentration in all the tests. While most of the results in the two reports were from laboratory work, the instruments were also collocated downwind of several prescribed burns to test them in field situations. We found it difficult to obtain results from prescribed burning activities. Most of the prescribed burns were small and did not produce large amounts of smoke. More importantly, these burns were conducted during conditions that allowed the smoke to disperse. Regulatory requirements dictate that airsheds must be in suitable conditions before burning to prevent smoke from impacting populated areas. Most of the smoke from the prescribed burns lofted high into the air, far above our instruments. The numerous, intense fires during Fire Storm 2000 provided us with an excellent chance to evaluate the real-time instruments during natural wildfire conditions.

Fire Storm 2000

The fire season of 2000 shaped up as one of the biggest in the last four decades. Fire scorched significant portions of northern Idaho and western Montana from mid-July to mid-September. By August 14, the fires in the Bitterroot Valley had burned more than 120,000 acres. Numerous smoke alerts and advisories were issued for the communities in the Bitterroot Valley and for Missoula. By the end of August, fires had burned 307,000 acres of the 1.6-million-acre Bitterroot National Forest and an additional 49,000 acres of State and private forests (figure 2). Heavy rains and snow at higher elevations during early September allowed firefighters to effectively manage the wildfires. A total of 900,000 acres had been burned in Montana. Another 1,250,000 acres had been burned in Idaho.

Smoke from the fires followed local weather patterns, affecting most communities in western and central Montana. Wind patterns and terrain caused the smoke to travel north and east (figure 3). Communities around Hamilton were subjected to much higher concentrations of smoke particulate than communities around Missoula.

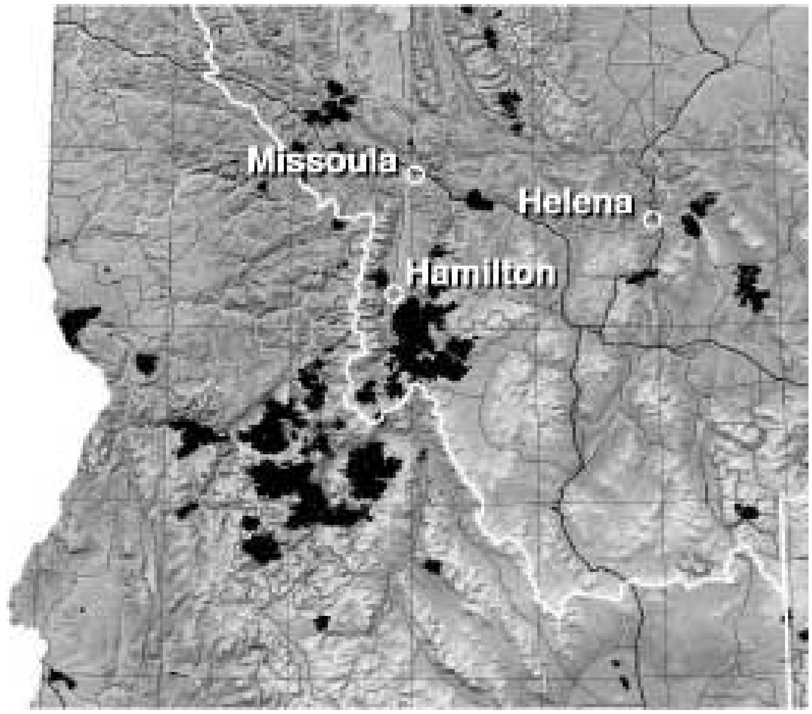


Figure 2—The cumulative burned areas in central Idaho and western Montana beginning July 4 to September 17, 2000 (available on the Internet at: *http://www.fs.fed.us/r4/rsgis_fire/images_sep2000/idmtwy_cm_burn00-09-18.jpg*).

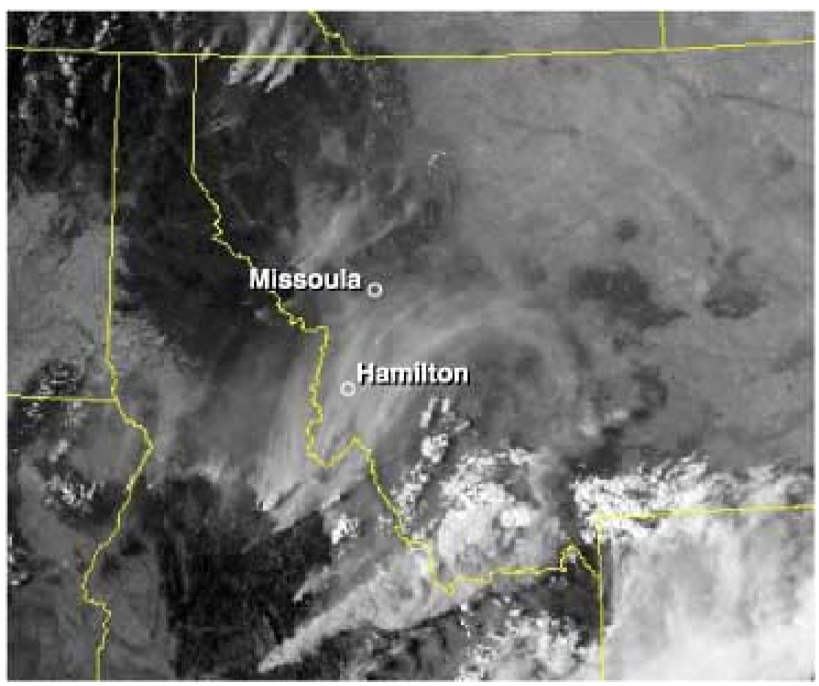


Figure 3—Smoke from fires in Idaho and Montana moving to the northeast on August 17, 2000 (available on the Internet at: *http://www.fs.fed.us/r4/rsgis_fire/images_aug2000/smk0008180020.jpg*).

Regional Air Quality

The smoke from the fires had a severe impact on air quality in the communities across western Montana. Most of the larger communities, including Missoula and Hamilton, have EPA-approved federal reference method (FRM) $PM_{2.5}$ gravimetric samplers. Several communities also have tapered element oscillating microbalance (TEOM) instruments to provide real-time particulate level information to air-quality specialists. For those communities with a TEOM instrument, air-quality stage alerts were determined using information from that instrument. Other communities used visual techniques to estimate particulate concentrations.

Air Quality Standards

The Clean Air Act, which was last amended in 1990, requires the EPA to set national ambient air quality standards (NAAQS) for pollutants considered harmful to public health and the environment. The Clean Air Act establishes two types of national air quality standards. *Primary standards* set limits to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly. *Secondary standards* set limits to protect public welfare, including protection against decreased visibility, damage to animals, crops, vegetation, and buildings. Both PM_{10} (particulate less than 10 microns in diameter) and $PM_{2.5}$ are established *primary* and *secondary* pollutants.

The limits set by EPA for PM_{10} are 50 $\mu g/m^3$ for the annual average and 150 $\mu g/m^3$ for the 24-h average. Limits set by EPA for criteria pollutant $PM_{2.5}$ are 15 $\mu g/m^3$ for the annual average and 65 $\mu g/m^3$ for the 24-h average.

The EPA developed an air quality index (AQI) to provide a consistent and easy way to understand air pollutant concentrations and their health implications. The EPA AQI values are based on $PM_{2.5}$ for the 24-h average. To help communities further understand the air quality issues associated with forest fire smoke, the Montana State Department of Environmental Quality (MT DEQ) established AQIs for 8-h and 1-h average concentrations. Table 1 shows the values and associated health risks for all three AQIs.

Table 1—Air quality index (AQI) as established by the U.S. Environmental Protection Agency and the Montana Department of Environmental Quality. Values are for 1-, 8-, and 24-h averages.

Categories	Health effects	Cautionary statements	EPA 24h AQI ($\mu g/m^3$)	MT DEQ 8h AQI ($\mu g/m^3$)	MTDEQ 1h AQI ($\mu g/m^3$)
Good	None	None	0–15	0–22	0–38
Moderate	Possibility of aggravation of heart or lung disease among persons with cardiopulmonary disease and in the elderly.	None	15–40	22–58	38–101
Unhealthy for sensitive groups	Increased likelihood of respiratory symptoms in sensitive individuals. Aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and in the elderly.	People with respiratory or heart disease, the elderly, and children should limit prolonged exertion.	40–65	58–93	101–164
Unhealthy	Increased aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and in the elderly; increased respiratory effects in the general population.	People with respiratory or heart disease, the elderly, and children should avoid prolonged exertion; everyone else should limit prolonged exertion.	65–150	93–215	164–376

Table 1 continued. . .

Very unhealthy	Significant aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; significant risk of respiratory effects in the general population.	People with respiratory or heart disease, the elderly, and children should avoid any outdoor activity; everyone else should avoid prolonged exertion.	150–250	215–358	376–626
Hazardous	Serious aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and in the elderly; serious risk of respiratory effects in the general population.	Everyone should avoid any outdoor exertion; people with respiratory or heart disease, the elderly, and children should remain indoors.	250 +	358 +	626 +

The MT DEQ also established visibility ranges (table 2) to help communities without real-time monitoring equipment estimate particulate concentrations. The MT DEQ established these visibility ranges using empirical data collected from the Automated Surface Observing System visibility sensor located at the Helena airport and particulate concentrations collected nearby.

Table 2—Visibility ranges defined by the Montana Department of Environmental Quality corresponding to the department's air quality index.

Montana Department of Environmental Quality (DEQ) visibility categories	
Category	**Visibility (miles)**
Good	> = 11.6
Moderate	4.45–11.5
Unhealthy for sensitive groups	2.75–4.44
Unhealthy	1.2–2.74
Very unhealthy	0.7–1.1
Hazardous	< 0.7

Missoula and Hamilton Air Quality

The real-time instruments deployed by MTDC for this evaluation were operated almost continuously from about August 10 through the end of the month. Data from the real-time instruments were corrected using empirical formulas developed as a result of the evaluation. The following summary of the air quality in Missoula and Hamilton is based on the results from the real-time instruments' corrected data.

In Hamilton, the 1-h running average peak for $PM_{2.5}$ reached as high as 500 $\mu g/m^3$ and the running 24-h average reached as high as 284 $\mu g/m^3$ (figures

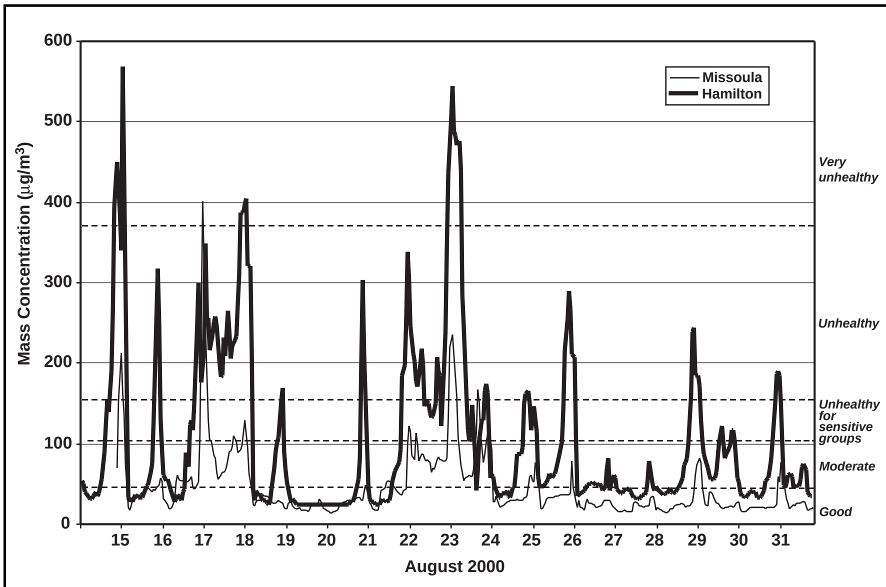


Figure 4—The estimated 1-h running mass concentration averages for $PM_{2.5}$ in Missoula and Hamilton, MT, during August 2000. Results are from the corrected values of the MIE DataRam real-time particulate monitor. Hazard category levels for forest fire smoke were determined by the Montana Department of Environmental Quality.

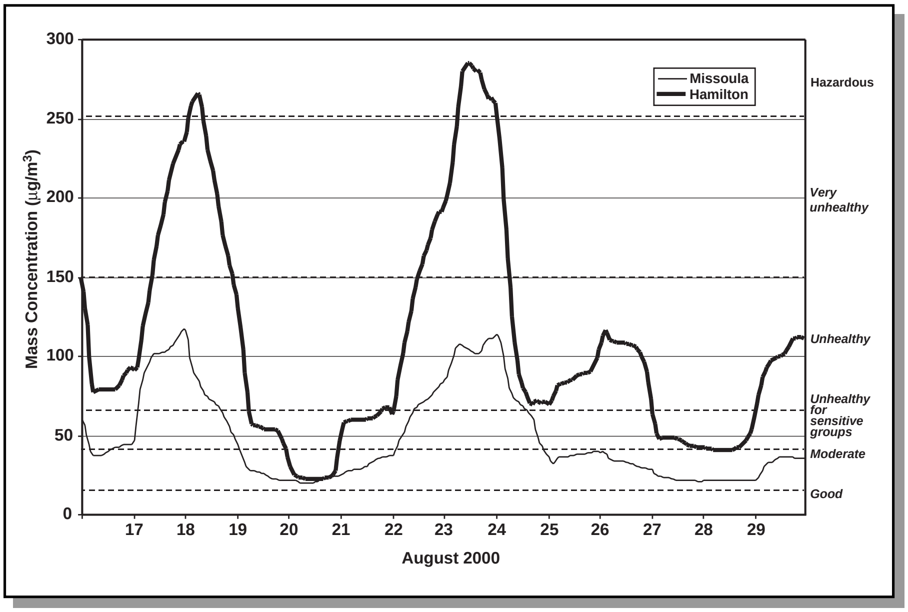


Figure 5—The estimated 24-h running mass concentrations for $PM_{2.5}$ in Missoula and Hamilton, MT during August 2000. Results are from the corrected values of the MIE DataRam real-time particulate monitor. Hazard category levels were determined by the Montana Department of Environmental Quality for forest fire smoke.

4 and 5). The 24-h $PM_{2.5}$ average reached the hazardous level as described by the EPA and MT DEQ AQI. Missoula reached running 1-h average peaks of 400 $\mu g/m^3$ and 24-h average peaks of 204 $\mu g/m^3$ for $PM_{2.5}$.

Figures 6 and 7 show the percentage of time the air quality was in the various hazard categories based on the $PM_{2.5}$ AQI for Hamilton and Missoula. From August 14 to 30, the air quality index for the general public in Hamilton was categorized as unhealthy or worse about 67 percent of the time. If you include sensitive people (those with respiratory or heart disease, the elderly, and children), the air quality index was unhealthy or worse 93 percent of the time. Missoula's air quality was much better with no hazardous or very unhealthy peaks. The air quality index could be categorized as unhealthy 28 percent of the time from August 11 to 30, or unhealthy for 39 percent of the time if sensitive groups are included.

Daily 24-h $PM_{2.5}$ averages were calculated for Missoula and Hamilton (figure 8). The proposed 24-h EPA $PM_{2.5}$ standard of 65 $\mu g/m^3$ is shown in the graph. Hamilton exceeded this level 10 times from August 14 to 30, while Missoula exceeded the level 6 times from August 11 to September 1.

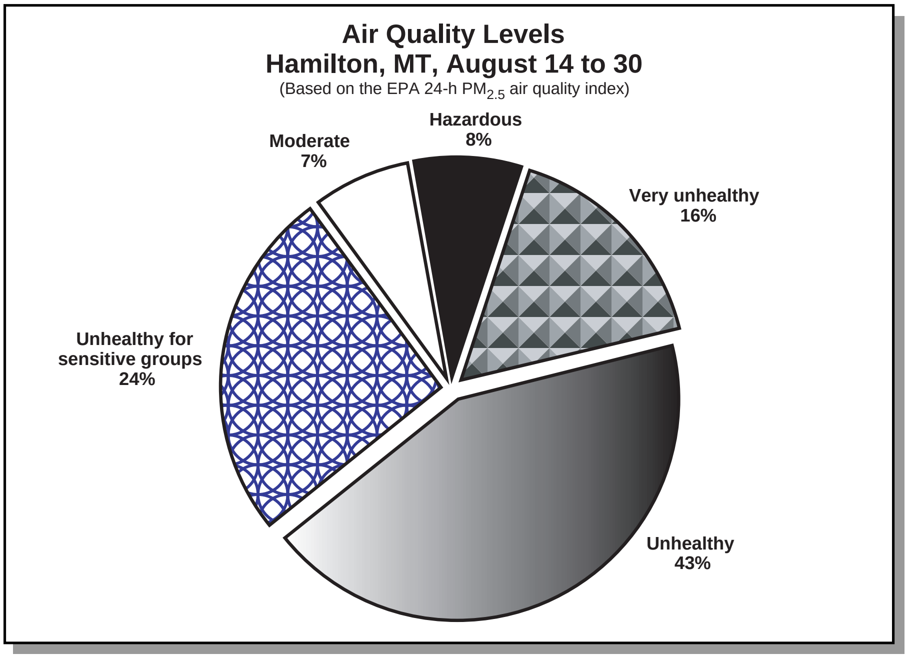


Figure 6—Air quality levels in Hamilton, MT, from August 14 to 30, 2000. The hazard categories are based on the U.S. Environmental Protection Agency air quality index for particulates smaller than 2.5 $\mu g/m^3$.

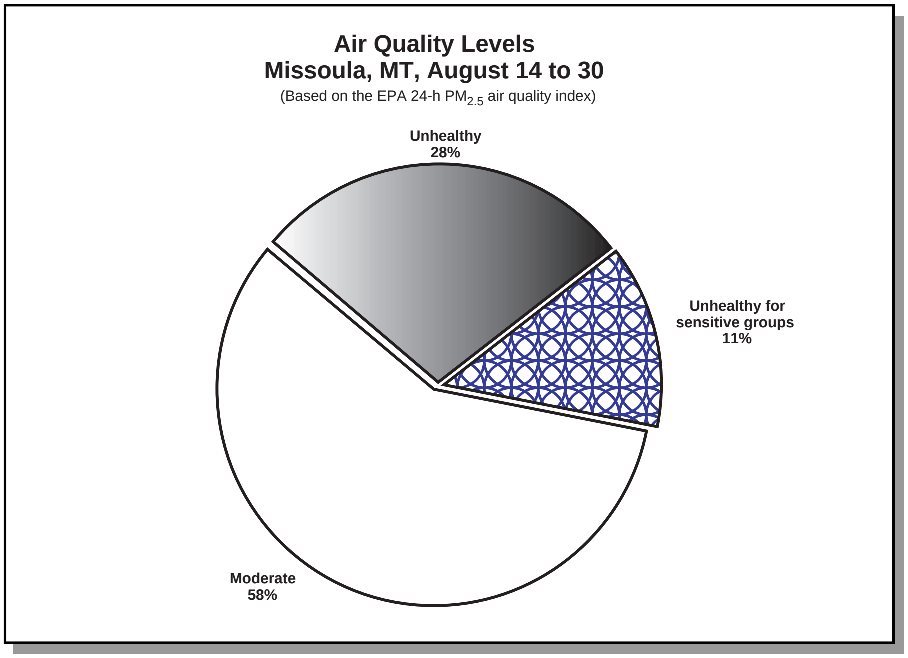


Figure 7—Air quality levels in Missoula, MT, from August 14 to 30, 2000. The hazard categories are based on the U.S. Environmental Protection Agency air quality index for particulate matter smaller than 2.5 $\mu g/m^3$.

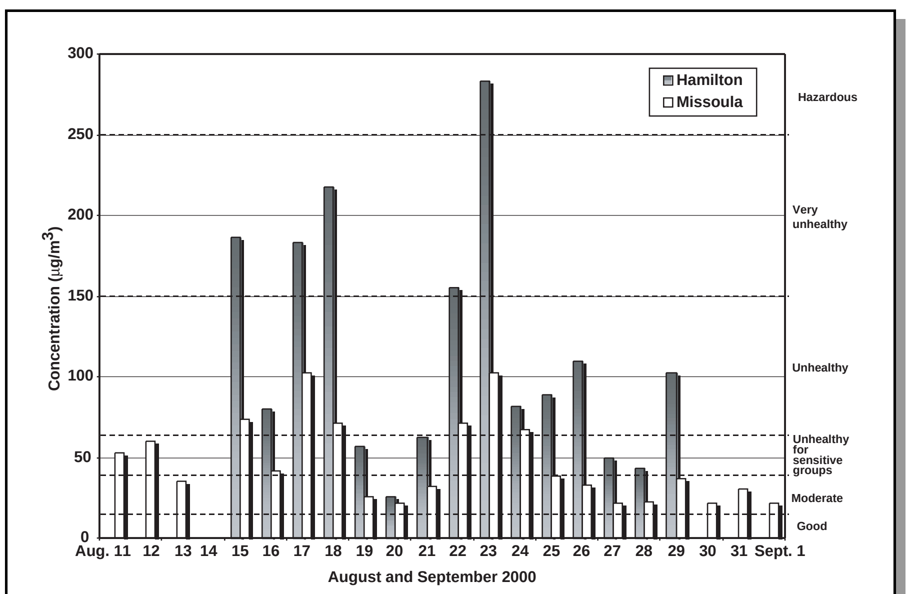


Figure 8—The estimated 24-h (midnight to midnight) $PM_{2.5}$ concentrations for Missoula and Hamilton, MT, from August 11 to September 1, 2000. Results are from the corrected MIE DataRam real-time particulate monitor.

- End of Part 1 -