UNIT 5 – SMOKE IMPACTS

LESSON C - EFFECTS OF SMOKE ON VISIBILITY

INSTRUCTIONS TO THE INSTRUCTOR

This lesson discusses why and the way smoke particles scatter, refract, and absorb light. Please refer to the Smoke Management Guide (Hardy and others 2002) and the Introduction to Visibility (Malm 1999). These two publications provided many of the graphics and written word for this lesson. There is also a video produced by the Cooperative Institute for Research in the Atmosphere (CIRA) entitled "Understanding Regional Haze" that may be presented to the students. Visibility and safety considerations are discussed in the Safety and Nuisance Impacts Lesson.

The instructor should discuss local conditions and use examples relating the Clean Air Act to Mandatory Class I areas and National Visibility Goal. Also, the management direction to increase the use of prescribed fire; public perception of fire and the direction from EPA and the states for clean air should be addressed.

When illustrating the various strategies and techniques for reducing smoke outputs use slides that are applicable to local or regional situations.

It is the instructor's responsibility to be familiar with questions related to the respective lesson and the rest of the examination.

DETAILED LESSON OUTLINE

COURSE: Smoke Management Techniques (Rx-410)

UNIT: 5 - Smoke Impacts

LESSON: C - Effects of Smoke on Visibility

SUGGESTED TIME: 30 Minutes

TRAINING AIDS: Overhead projector, or personal computer with LCD projector and presentation software; flip chart; table; name cards; flipchart paper with pens

OBJECTIVES: Upon completion of this lesson, the student will:

1. Describe how smoke contributes to impaired visibility and regional haze.

2. Discuss how visibility impairment relates to the Clean Air Act, National Visibility Goals, and Class I areas.

OUTLINE	AIDS & CUES
TITLE SLIDE, UNIT 5C. VISIBILITY	5C-01-Rx410-EP
PRESENT AND REVIEW LESSON OBJECTIVES.	5C-02-Rx-410-EP
This lesson will first describe how smoke causes visibility, regional haze, and safety concerns. The lesson will then focus on the visibility and regional haze and how it relates to regulations.	
Why are we concerned about visibility? Here are a few reasons:	5C-03-Rx410-EP
• Safety (visibility impairment can lead to automobile accidents)	

OUTLINE	AIDS & CUES
• Visibility Protection (the 1977 Clean Air Amendment requires the prevention of any future and remedying of any existing impairment of visibility in Class I Federal areas) • Regional Haze (This is haze and visibility impairment produced by a multitude of sources and the states are required by the Clean Air Amendment to show reasonable progress toward prevention and remedying) • Other concerns such as social values (real estate, recreation, and tourism)	
To begin the lesson, let's start off with a relatively clean air situation. This is the Shining Rock Wilderness area in North Carolina during a very clear day episode where a person can see over 100 miles (good visibility). The following pictures are from stationary cameras that periodically take pictures of mountain targets in the wilderness to monitor visibility and haze.	5C-04-Rx410-EP
These mountains are obscured over 44 percent of the time from moisture in the air and clouds.	5C-05-Rx410-EP
Regional haze conceals the mountain targets in the Shining Rock Wilderness 46 percent of the time.	5C-06-Rx410-EP
This slide shows the visibility impairment from good, medium, poor, and bad days in the Shining Rock Wilderness.	5C-07-Rx410-EP
Visibility impairment is associated with discoloration, haziness, and loss of detail and scenic features. How visibility impairment manifests itself depends on the extent and distribution of small particles in the atmosphere.	5C-08-Rx410-EP
Visibility impairment can be classified into 3 general categories. These categories include layered haze, plume haze, and uniform haze.	5C-09-Rx410-EP

OUTLINE	AIDS & CUES
Layered haze is when the atmosphere is stable (inversion) and pollution can be trapped near the ground and the haze will be in a layer. This photograph is of layered haze from wildfires near Missoula, Montana. A plume haze occurs when pollution is emitted from a single source into an elevated stable layer. This photograph of a plume haze is from a prescribed fire near Mt. Shasta. Uniform haze occurs when pollution degrades visibility uniformly throughout the atmosphere. A uniform haze that moves through the atmosphere from one region to another and extends across a large geographical region, is called regional haze. Regional haze causes most of the visibility impairment. This is a photograph of uniform haze in the Shining Rock Wilderness.	
In order to understand visibility impairment, you need to understand the physics of light. Visible light is the vibration of electric and magnetic fields in the .4 to .7 micron wavelength range. The energy in light is carried by discrete packages called photons. The wavelength is similar to the length between the crest of two ocean waves. Blue light has a wavelength of about 0.45mm, green light has a wavelength of about 0.55 mm, and red light wave length of about 0.65mm. X-rays have smaller wavelengths than light and infrared, microwaves, and radar waves have wavelengths much longer than light waves.	5C-10-Rx410-EP 5C-11-Rx410-EP
Surface molecules of objects absorb and reflect photons of visible light. White light, which is composed of all “colors” of photons, strikes an object. If the object is white, photons of every color are reflected such as with this egg. However, if some of the photons are absorbed while others are reflected, the object will appear to be colored. Surface molecules of this apple captured all visible light photons except red.	5C-12-Rx410-EP

OUTLINE	AIDS & CUES
Atmospheric visibility is influenced by scattering and absorption by light particles and gases. The particles absorb, refract, reflect, and diffract light. In certain instances, the light supplies energy to the particle and the particle will release thermal energy and/or fluorescence.	5C-13-Rx410-EP
When a beam of white light (consisting of all colored photons) passes through a haze of small particles, it is generally the blue photons that are scattered in various directions and give the particles a bluish tint. Smoke contains very small particles that are often the diameter that is equal to or smaller than blue light and they will have a bluish appearance. When particles are near or larger than the wavelength of light, photons of all colors are scattered and a whitish appearance will occur.	5C-14-Rx410-EP 5C-15-Rx410-EP
The upper left photo is of smoke with very small particles that are less that the wavelength of light and refract blue light. The lower right photograph shows smoke particles that have grown to about the size of the wavelength of visible light in a humid environment. The larger wavelength particles refract visible light thus appearing whitish.	5C-16-Rx410-EP
As shown by this graph, most smoke particles have a diameter around 0.1 ¼m with a range of 0.08 ¼m to 0.7 ¼m. Visible light wavelengths: ~.4 -.7 ¼m.	5C-17-Rx410-EP
Particles having a diameter about the same as the wavelength are the most effective at scattering light. Consequently since smoke particles are about the same diameter as the wavelength of light, they scatter about 85% of the light that strikes them.	5C-18-Rx410-EP
Wildland fire smoke is primarily made up of elemental carbon and organic carbon (particulate matter).	5C-19-Rx410-EP

OUTLINE	AIDS & CUES
Fine particles most responsible for visibility impairments are sulfates, nitrates, soil dust, organic compounds, and elemental carbon (soot). Sulfates, nitrates, soil, organic carbon, and soil dust scatter light. Elemental carbon absorbs light. Since wildland fire smoke is primarily made up of elemental carbon and organic carbon, smoke is an excellent scatterer and absorber of light.	5C-20-Rx410-EP
This slide shows the organic carbon that scatters visible light and is white in color. The elemental carbon absorbs light and is black in color.	5C-21-Rx410-EP
What happens to smoke particles once lofted into the atmosphere? Smoke is made of very small particles less than 1 micron in size. It takes approximately 35 days for a particle less than 1 micron in size to drop 1000 feet. It has been estimated that the life span of a smoke particle is about 2 to 3 weeks. Note: Particles in this diameter range form excellent cloud condensation nuclei and may assist in the formation of rain droplets and can be removed from the atmosphere. Since the particles provide excellent condensation nuclei, they also assist in the formation of fog. Thus, the smoke particles not only cause visibility impairment by scattering and absorbing light, but may also cause fog to be formed before the dew point is reached, thus causing visibility and automobile safety concerns.	5C-22-Rx410-EP

OUTLINE	AIDS & CUES
Visibility/Visual Range: Visibility is most often thought of in terms of visual range or the furthest distance a person can see a landscape feature. The scientific definition of visual range is the farthest distance at which one can see a large black object against the sky. Maximum visual range with only air molecules in the air is 240 miles. Even without the influence of human caused air pollution, visibility would not reach the 240-mile limit because light extinction can occur naturally due to scattering caused by molecules that make up the atmosphere. This is called Rayleigh scattering and is the reason the sky is blue. In the real world, people sense reduced visibility if a distant object that is usually visible cannot be seen; nearby objects look hazy; and if a layer of white, gray, or brown "pollutant" is seen.	5C-23-Rx410-EP 5C-24-Rx410-EP
Visibility is the process of how light is absorbed, scattered, and perceiving the environment through the human eye and brain. This hiker sees a landscape feature as light is reflected to form an image, however, particles and gases suspended in the view path can scatter or redirect image forming light as it travels to the eye. Sunlight, light from the clouds, and ground reflected light all impinge on and scatter from particulates located in the site path. Some of the scattered light remains in the sight path and at times it can become so bright that the image essentially disappears. Through this scattering process, some image forming light is removed from the site path and some light is scattered into the light path interfering with the view. Scattered light has a significant impact on the view. In addition, image-forming light is absorbed by particles and gases and taken out of the light path before reaching the viewer's eye. Absorption processes contribute less to visibility impairment than the scattering processes. The sum of scattering and absorption processes is called light extinction. Extinction or loss of light is directly related to the concentration of gases and particles in the atmosphere.	5C-25-Rx410-EP

OUTLINE	AIDS & CUES
These four pictures show the effect of progressively shifting sun angle on the appearance of a vista as seen from Island in the Sky, Canyonlands National Park. At 0600, the sun-angle-observer vista geometry results in a large amount of scattered light with a limited amount of reflected light from the vista. At 1200 noon, the opposite occurs. Scattered light is minimized and reflected light from the vista is at its maximum.	5C-26-Rx410-EP
This slide shows the 1996-1998 average visual range over the United States. Currently, average visual range in the eastern United States is about 15-30 miles, or about one-third of the estimated natural background for the East. In the West, visual range currently averages about 60-90 miles, or about one-half of the estimated natural background for the West. Notice how much more impaired visibility is in the East versus the West. The current visual range was measured from the Interagency Monitoring of PROtected Visual Environments (IMPROVE) network.	5C-27-Rx410-EP
National Visibility Goals The 1977 amendments to the Clean Air Act established a national goal of "the prevention of any future, and remedying of any existing impairment of visibility in mandatory Class I Federal areas which impairment results from manmade air pollution." States are required to develop implementation plans that make "reasonable progress" toward the national visibility goal. This is similar to the requirement by the Clean Air Act that requires the states to manage smoke for the health and welfare of the public.	5C-28-Rx410-EP

OUTLINE	AIDS & CUES
The visibility regulations require states to make "reasonable progress" toward the Clean Air Act goal of "prevention of further, and future remedying of any existing, impairment, of visibility…". The regional haze regulations did not define visibility targets, but gave the states flexibility in determining reasonable progress. The rules require states to establish goals for each affected Class I area to: 1) Improve visibility on the haziest 20 percent of the days and 2) ensure no degradation occurs on the clearest 20 percent of the days over the period of each implementation plan. A visibility baseline will be determined from a national network of visibility monitors (IMPROVE) representing Class I areas.	5C-29-Rx410-EP
This slide is a map of the mandatory class I Federal areas of the United States. These areas are subject to the tightest restrictions on how much additional pollution, or increment, can be added to the air. Class I areas include Forest Service wilderness, national memorial parks over 5,000 acres, national parks exceeding 6,000 acres, and international parks.	5C-30-Rx410-EP
Federal land managers have somewhat conflicting roles when it comes to protecting visibility in the Class I areas they manage. On the one hand, they are given the responsibility by the Clean Air Act for reviewing Prevent Significant Deterioration (PSD) permits of major new and modified stationary sources and commenting to the state on whether there is a concern for visibility impacts. On the other hand, the federal land managers also use wildland fire which emits visibility impairing pollutants.	5C-31-Rx410-EP
How is this conflict resolved? Wildernesses are managed to preserve and protect natural areas. Smoke and visibility impairment from wildland fire that closely mimics what would occur naturally is generally viewed as acceptable; while visibility impairment from "unnatural" pollutants and unnatural pollution sources is not.	5C-32-Rx410-EP

OUTLINE	AIDS & CUES
Regional haze is visibility impairment produced by a multitude of sources and activities that emit fine particulates and their precursors, and are located across a broad geographical region. This contrasts with visibility impairment that can usually be traced to a single, very large polluting source. Natural and current regional visibility varies significantly due to humidity, natural and anthropogenic emissions	5C-33-Rx410-EP
This slide shows the effect that different levels of regional haze or uniform haze have on a Glacier National Park, Montana vista. The photos were taken near Apgar on the southwestern end of Lake McDonald. The atmospheric particulate concentrations associated with the photographs correspond to 7.6, 12.0, 21.7, and 65.3 mm.	5C-34-Rx410-EP
Summary Visibility is the process of how light is absorbed, scattered, and perceiving the environment through the human eye and brain. Image-forming information from an object is reduced (scattered and absorbed) as it passes through the atmosphere to the human observer. A majority of the particles generated by wildland fires are very small and are excellent scatterers of light. Regional haze is visibility impairment produced by a multitude of sources and activities that emit fine particulates and their precursors, and are located across a broad geographical region. The Clean Air Act establishes National Visibility Goals that are administered by the states.	5C-35-Rx410-EP
REVIEW UNIT OBJECTIVES.	5C-36-Rx410-EP

REFERENCES

Cooperative Institute for Research in the Atmosphere. 2002. Video—Understanding Regional Haze. 30 minutes

Hardy, Colin C.; Roger D. Ottmar; Janice L. Peterson; John E. Core, and Paula Seamon. 2002. Smoke management guide for prescribed and wildland fire—2001 edition. PMS 432-2. Boise, ID: National Wildfire Coordinating Group, National Interagency Fire Center. 226 p.

Malm, William C. 1999. Introduction to visibility. Cooperative Agreement Number CA2350-97-001: T097-04, T098-06, Cooperative Institute for Research in the Atmosphere, NPS Visibility Program, Colorado Sate University, Fort Collins, CO. 68 p.