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Project Summary

A Review of Methods for Remote Sensing of Atmospheric Emissions from Stationary Sources

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This document provides a review of several remote monitoring systems that can be used to detect the presence of, or determine the concentration of, pollutant emissions in air. Remote sensing technologies were categorized as passive or active depending on the light source employed in the system. The description of techniques is organized into three sections: commercially available instruments, developing technologies, and potential developments. A brief discussion of practical considerations related to the use of remote sensing for air pollution emissions monitoring is also presented.

This Project Summary was developed by EPA's Environmental Monitoring Systems Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The surveillance of air pollutant source emissions is of concern to regulators, process operators, process engineers, air pollution control engineers, and air pollution researchers. The primary objective of this research was to provide a summary of remote sensing capabilities that have been used for, or are applicable to, air pollutant emissions monitoring. Many of these methods were identified.

The remote sensing technologies reviewed in this report are limited to those that rely on the interaction of a light source and some atmospheric property to detect the presence of an atmospheric constituent. Remote sensing technologies have been divided into passive systems and active systems. Passive systems use some natural light source; in active systems, a light source is included as a part of the instrument design.

This report presents an overview of remote sensing technologies and of the physical and chemical principles that are related to remote sensing. The specific remote sensing instruments identified during this effort are described. Practical considerations related to the application of methods for remote sensing of air pollutant emissions are presented.

Techniques and Principles

The basic physical principles behind many remote sensing techniques are discussed in general terms. As throughout the rest of this report, this section discusses passive and active techniques separately. Although passive techniques are often simpler, more mobile, and less expensive than active techniques, their use is often restricted to daylight hours and to good meteorological conditions.

Passive techniques may operate in either the emission mode or the adsorption mode of molecular spectroscopy. In the emission mode, the

target gas (e.g., a heated plume) produces the radiation that is detected. In the absorption mode, an external but natural radiation source (e.g., sunlight) interacts with the target gas and is detected.

The most common light sources being used for active techniques are lasers. They are chosen for the high power that they have available at specific wavelengths of interest. However, with this advantage comes a potential eye hazard.

Summary of Remote Sensing Technologies

Both commercially available instruments and developing technologies are discussed in this section. Table 1 summarizes the methods and their developmental status. Such information as cost, weight, and power requirements are given for the commercially available instruments. In many cases, specification sheets for these instruments are provided. There are more passive than active instruments commercially available. The relative cost of these two classes of instruments appears to be a determining factor in their availability.

Practical Considerations

Many applications of remote sensing technologies to source emissions monitoring have been discovered and several have become commercial ventures. In general, passive systems have been applied to routine monitoring of source emissions such as smokestack-type emissions, and active techniques have been applied more often to area or line sources involving potential accidental releases of explosive or hazardous materials. The companies that offer commercial pulsed laser measurement systems also offer van-mounted systems for lease at considerably less cost than the purchase price.

Remote sensing of air pollutants can be applied to a significant list of pollutant species. Advancements and research can provide capabilities for the measurement of many more air pollutants. Technologies exist that can be used to measure almost any air pollutant by remote sensing principles. The investment of labor and money to develop, build, and test a system can often be significant and even prohibitive; thus, careful planning is required for projects concerned with emissions monitoring by remote sensing. In many instances, the benefits would justify the potential costs, but every application should be considered individually.

There are limitations to passive remote sensing systems that rely on natural radiation. One is the dependence on favorable meteorological conditions. There are wide variations of the light source intensities in different locations, during different seasons, and during periods of the same day at the same location. Compensation for the variations often requires additional steps in the signal processing and data reduction, and short-term variations still contribute to error. Another limitation of passive remote sensors is the inability to determine the amount of emissions as a function of distance from the detector. Thus, range-resolved spatial mapping of the gas usually cannot be obtained. Rather, the measurement is the integral concentration of emissions along the entire line of sight. The quantity measured is optical depth, the product of a concentration and a pathlength. These limitations do not preclude the use of passive devices for remote sensing of source emissions. Passive sensors are generally simpler, more convenient, easier to operate, and easier to maintain than active sensors. They are also usually considerably less expensive than active sensors.

Active systems have severe limitations as well. They are often cumbersome, they sometimes require special power supplies, and optics alignment can involve regular maintenance and attention. Pulsed laser systems, used to obtain range-resolved measurements, require sophisticated signal-processing electronics and significant data storage capacity. The operation of the system, data handling tasks, data interpretation, and routine system maintenance often require a skilled technician trained for the task.

Advantages of active techniques are related to extent of coverage either spatially or temporally. The spatial coverage offered by either computer-controlled or mobile, mounted systems is obvious. A sweep of an entire chemical complex can be accomplished in several minutes by using a computer-controlled laser-based system. A mobile system mounted on a truck or a van can define the extent and characteristics of a widely dispersed power plant plume in a short time.

The temporal coverage provided by continuous long-path systems makes them well-suited for perimeter monitoring and pipeline surveillance in cases where hazardous materials can be released inadvertently. Long-lasting light sources and simple electronics that focus on alarm level detection m these systems capable of continuc unattended operation for long period time. Often, lasers are not required even desired for this type of applicat and the simplicity that can be tolera brings the cost down to levels c petitive with passive remote sens systems.

Table 1. *Remote Sensing Methods for Source Emissions Measurements and their Development Status*

Method Class	Method	Developmental Status
Passive	Radiometers, heterodyne	Developing technology
	Radiometers, imaging	Commercially available
	Spectrometers	Not applicable
	Interferometers	Commercially available
	Correlation spectrometers, dispersive	Commercially available
	Correlation spectrometers, nondispersive	Commercially available
Active	Long-path infrared absorption	Commercially available
	Lidars, atmospheric (Mie) backscatter	Commercially available
	Lidars, differential absorption	Commercially available
	Lidars, fluorescence	Undeveloped
	Lidars, Raman backscatter	Commercially available
	Lidars, Doppler	Developing technology
	Lidars, wedge absorption	Developing technology
	Gas imaging	Developing technology

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The complete report, entitled "A Review of Methods for Remote Sensing of Atmospheric Emissions from Stationary Sources," (Order No. PB 88-190 483/AS; Cost: $14.95, subject to change) will be available only from:

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