

FOREWORD

This bibliography was prepared while Mr. Brooks was pursuing graduate studies at Iowa State University. The coauthor, Professor Thomson is the Professor of Forestry at Iowa State University.

Since the subject matter is of interest to the Department of Defense community, it is published as a TOPOCOM Special Bibliography.

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AN ANNOTATED BIBLIOGRAPHY OF
REMOTE SENSING OF AIR AND WATER POLLUTION

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This annotated bibliography represents an attempt to compile a complete list of literature published between 1965-1970 on the subject of remote sensing of air and water pollution. The periodicals examined completely for articles include *Applied Science and Technology*, *Reader's Guide to Periodical Literature*, *Air Pollution Control Association Abstracts*, *Journal of the Air Pollution Control Association*, *Journal of the Water Pollution Control Federation*, *Atmospheric Environment*, *Photogrammetric Engineering*, *Photogrammetria*, Papers from the 1969 and 1970 Annual Meetings of the American Society of Photogrammetry, *Journal of Applied Meteorology*, *Journal of Atmospheric and Terrestrial Physics*, *Bulletin of the American Meteorological Society*, Symposia of Remote Sensing of the Environment, and the *International Journal of Air and Water Pollution*. Articles from periodicals such as *Science*, *Nature*, *Electronics Technology*, *Power*, *Review of Scientific Instruments*, etc. were either listed in *Applied Science and Technology* or *Reader's Guide to Periodical Literature* or were listed as references in articles obtained previously. No attempt was made to completely search these periodicals for articles.

The listings in this bibliography are arranged according to subject matter, and alphabetically within the subjects as follows:

Air Pollution

- (1) Airborne and Spacecraft Surveillance
- (2) A Photogrammetric Method
- (3) Laser and Lidar Studies
- (4) The Integrating Nephelometer
- (5) The Non-Dispersive Infrared Analyzer
- (6) The Optical Interferometer
- (7) Computerized Air Monitoring Systems
- (8) Miscellaneous

Water Pollution

- (1) General Remote Sensing of Water Pollution
- (2) Aerial Panchromatic Photography
- (3) Aerial Infrared Imagery
- (4) Radiophase
- (5) Earth Resistivity Measurements

General Remote Sensing

An alphabetical listing, by authors, including titles of published papers, of locations where research in pollution has been carried on during the last year is included.

AIR POLLUTION

Airborne and Spacecraft Surveillance

Adams, D. F., R. K. Koppe, "Instrumenting Light Aircraft for Air Pollution Research." *Journal of the Air Pollution Control Association*, Vol. 19, No. 6, p. 410-415, Jan. 1969.

The airborne instrument package described can measure and record up to 27 pollutant and flight variables from a Cessna Skymaster center-line thrust light twin. Real-time analysis instrumentation include non-dispersive infrared analyzers for CO₂, CO, and hydrocarbons, conductivity and coulometric analyzers for sulfur dioxide and sulfur-containing gases, and Charlson-Ahlquist visual range nephelometer. A Battelle "bulk sampler" is used to collect particles for weighing and microscopic examination. Aircraft and meteorological variables recorded are temperature, humidity, altitude, indicated air speed, rate of climb, and magnetic heading.

Barringer, A. R., B. C. Newbury, A. J. Moffat, "Surveillance of Air Pollution From Airborne and Space Platforms." *Proceedings of the Fifth Symposium on Remote Sensing of the Environment*. Sept. 1968, p. 123.

The teaming of remote sensing devices in both aircraft and spacecraft makes feasible measurements and surveys which were impossible before. The role of remote sensing devices that can monitor the broad regional and global picture in both the upper and lower atmosphere is a very important one. A new instrument, called a correlation spectrometer, has been developed for remote sensing of gases from both airborne and orbital altitudes. The equipment is described and results of two experiments are given. The two experiments were carried out over Washington, D.C. and over Toronto, Canada, and both gave promising results. Preliminary studies have been made of the feasibility of installing correlation spectrometers in spacecraft. The advantage of satellite studies will be in allowing studies of the global build-up of pollution. The nature of discharge of high altitude pollutants in heavy traffic airlines across the Atlantic and elsewhere can be studied. Mass flow determinations of urban areas, regional pollution dispersion and circulating patterns, and global pollution background can all be determined.

Also discussed in this paper are natural resource measurements related to pollutant monitoring techniques:

- (a) monitoring of volcanic emissions of sulphur dioxide and other gases to provide warnings of impending volcanic activity.

- (b) the detection of fumarole emissions as a guide to the location of sources of geothermal energy.
- (c) the measurement of trace gases emitted by oxidizing mineral deposits and the use of this information as a guide to exploration.
- (d) the measurement of gaseous emissions of iodine vapors associated with oil field brines as a guide to potential oil bearing regions.
- (e) the applications of optical remote sensing techniques to the detection of fish oil slicks associated with large schools of fish.

O'McCaldin, R., L. W. Johnson, "The Use of Aircraft in Air Pollution Research." *Journal of the Air Pollution Control Association*, Vol. 19, No. 6, p. 405-409, June 1969.

An instrumented single engine aircraft is used to characterize plumes from large emission sources such as power stations, forest fires, and gravel plants. Some of the experimental results of tracking suspended particles are given.

Randerson, D., "A Study of Air Pollution Sources as Viewed by Earth Satellites." *Journal of the Air Pollution Control Association*, Vol. 18, No. 4, p. 249, 1968.

Several photographs, taken by astronauts on various manned flights are shown to illustrate large scale dispersion of atmospheric pollutants. The pictures include smoke plumes in the Houston, Texas area, forest fires in Florida, and air pollution in Southeast Texas.

A Photogrammetric Method

Veress, S. A., "Determination of Concentration of Polluted Air by Photogrammetry." Papers from the 36th Annual Meeting of the American Society of Photogrammetry, p. 729, March 1970.

Examples are given, and results discussed, of experiments which show that a polluted air mass can be mapped with satisfactory accuracy by photogrammetry using a combination of vertical and oblique photographs. The extinction coefficient of any point was computed from the relation between the extinction coefficient measured by a nephelometer and the density measured by a microdensitometer. From this information a computerized density map was obtained. The advantages and disadvantages of the method are given.

Laser and Lidar Studies

Barrett, Earl W., Oded Ben-Dor, "Application of the Lidar to Air Pollution Measurement." *Journal of Applied Meteorology*, Vol. 6, June 1967, pp. 500-515.

A vertically aimed lidar (optical radar) system is described. The theories of the technique, description of its operation and some examples of lidar observations are given. Pictures of oscilloscope tracings of stagnant air over the Chicago area in August 1966 are shown and explained.

Collis, R. T. H., "Lidar Observations of Atmospheric Motion in Forest Valleys." *Bulletin American Meteorological Society*, Vol. 49, No. 9, Sept. 1968, pp. 918-922.

This paper discusses two sets of lidar observations made by Stanford Research Institute in connection with the U.S.F.S. insecticide spraying techniques. These observations occurring in 1966 and 1967 showed that lidar is very effective in tracking clouds of insecticide and smoke even when they cannot be seen. These particular observations were designed to provide new information about atmospheric motion in valleys but their implications for other uses are quite obvious.

Collis, R. T. H., "Lidar Observation of Cloud." *Science* 1965, No. 149, Aug. 27, 1965, p. 149.

The use and potential of lidar in observing clouds is discussed. Lidar (laser radar or optical radar) can detect much smaller atmospheric particles at its optical wavelength than radar at microwave wavelengths. Extremely intense pulses of monochromatic light are beamed using a transmitter that utilizes a lens system. The back-scattered light is measured using a telescope coaligned with the transmitter. Formation of stratus and fog can also be studied with this equipment.

Hamilton, P. M., "The Use of Lidar in Air Pollution Studies." *International Journal of Air and Water Pollution*. Pergammon Press, 1966, Vol. 10, pp. 427-434.

Trials with lidar (optical radar or laser radar) have indicated that it has two important roles to play in studying plume behavior--detect and track a plume and probe environment aerosol. This paper describes two examples of lidar soundings and the equipment.

Hamilton, P. M., K. W. James, D. J. Moore, "Observations of Power Station Plumes Using a Pulsed Ruby Laser Rangefinder." *Nature*, Vol. 210, No. 5037, pp. 724-725, May 4, 1966.

Observations made at Tilbury Power Station, England in July 1965 with a prototype pulsed ruby laser rangefinder are discussed. The behavior of the bouyant plume under stable changing atmospheric conditions can be readily

monitored by the rangefinder. Using this method, a plume can be tracked even though it cannot be seen by the human eye.

Hanst, P. L., J. A. Morreal. "Detection and Measurement of Air Pollutants by Absorption of Infrared Radiation." *Journal of the Air Pollution Control Association*, Vol. 18, No. 11, pp. 754-759, Nov. 1968.

A technique of detecting gaseous air pollutants by means of absorption of laser radiation is under development at the NASA Electronics Research Center. The two infrared lasers which appear to be the most useful for pollutant detection are the CO₂ laser and the I₂ laser. Each of these emits lines which fall within the infrared absorption bands of principal atmospheric pollutants and each can be operated continuously with a good power output.

Johnson, W. B., "Lidar Applications in Air Pollution Research and Control." *Journal of the Air Pollution Control Association*, Vol. 19, No. 3, pp. 176-179.

This paper discusses the fundamental capabilities and limitations of the lidar (laser radar) in air pollution research and control. The main areas discussed are: (1) observing the structure and height of surface-based mixing layers; (2) measuring the transport and diffusion of plumes and clouds of particulates; (3) remotely determining smokeplume opacity.

Masterson, J. E., J. L. Karney, W. E. Hoehne, "The Laser as an Operational Tool." *Bulletin American Meteorological Society*, Vol. 47, No. 9, Sept. 1966, pp. 695-701.

A brief history of the laser and a description of laser radar (lidar) equipment is given. Discussion of how cloud measurements are made, temperature inversions detected, haze, dust and fog layers measured are presented. Future uses for lidar are also briefly described.

Northend, C. A., R. C. Honey, W. E. Evans, "Laser Radar (Lidar) for Meteorological Observations." *Review of Scientific Instruments*, Vol. 37, No. 4, April 1966, pp. 393-400.

This paper describes the meteorological laser radar or lidar in great detail. This experimental lidar was modified for use in atmospheric studies conducted by the Environmental Sciences Division, Range Development Department, Pacific Missile Range, Point Mugu, California. Basic lidar system equations, system parameters, design, operation and recommendations for future development are discussed. The lidar is used to detect cloud and smog layers, locate temperature inversions

and aerosol layers, and ceiling height determination through rain or low level cloud structure.

Sandford, M. C. W., "Optical Radar Performance in Atmospheric Scattering." *Journal of Atmospheric and Terrestrial Physics*, Vol. 29, No. 12, Dec. 1967, pp. 1651-1656.

A method for describing the performance of an optical radar system is given. Using this method, comparisons between various optical radar systems can be easily made. Optical radar is used to measure the scattering of particles in the atmosphere.

Sandford, M. C. W., "Laser Scatter Measurements in the Mesosphere and Above." *Journal of Atmospheric and Terrestrial Physics*, Vol. 29, No. 12, Dec. 1967, pp. 1657-1662.

Laser measurements of particles in the mesosphere and above are discussed. It has been shown that seasonal variations in molecular density occur between 50 and 80 km. The existence of an aerosol layer at 90 km or higher cannot be detected with this equipment.

Schleusener, S. A., "A Gas Laser Aerosol Detection and Sizing Instrument." *Journal of the Air Pollution Control Association*, Vol. 19, No. 1, pp. 40-42, Jan. 1969.

Many of the new particle sizing instruments utilize light scattering principles to detect and size aerosol particles. The sensitivity of such instruments is good, although extensive light shielding and focusing methods must be used. A visible He-Ne gas laser cavity with its low gain is very sensitive to disturbances in its optical cavity and so may provide a new particle sizing approach.

— "AF Laser Radar Profiles Air Density at 100 km." *Electro-Technology*, Vol. 84, No. 1, July 1969, pp. 45-46.

The capability of a pulsed ruby laser radar to obtain density profiles of the atmosphere at altitudes up to 100 km has been demonstrated by the Air Force Cambridge Research Laboratories, Hanscom Field, Massachusetts together with the University of the West Indies, Kingston, Jamaica. Temperature profiles over a given region can be deduced from the density data. The laser system located at Kingston, Jamaica transmits a light pulse vertically upwards through the atmosphere. The backscattered signal is detected by an array of mirrors and a photomultiplier adjacent to the transmitter. The time between transmission of the pulse and reception of the scattered signals gives the heights from which scattering

occurs; the received intensity is a simple function of atmospheric density at these particular heights.

- "Laser Beam Helps Determine Smoke Pattern." *Power*, Vol. 111, Mar. 1967, p. 72.

A ruby laser scanning system to detect smoke dispersion was installed at Tilbury Power Station north of London, England, by Britain's Central Electricity Generating Board who is attempting to correlate the pattern of SO₂ pollution and stack discharge with concurrent weather conditions. The laser is very effective in tracking plumes so thin they cannot be seen and in this study plumes were tracked and recorded to a range of about 1¼ miles.

- "Laser Monitors Air Solids." *Chem & Eng News*, Mar. 6, 1967, Vol. 45, p. 23.

A laser radar system has been successfully used by Northwestern University Meteorologist Earl W. Barrett to monitor solid materials in smog and its density can be measured. A ruby laser with a wavelength of 0.6943 microns which can detect particles 0.1 microns in diameter is beamed vertically into the air. Back scattered light from particles in the air is received through a telescope and recorded as a trace on an oscilloscope. The trace is then photographed. Then the deflections, corresponding to various heights are measured and the information fed into a computer. The computer output gives the scattering function, solids, turbidity, and visibility for each height.

Air a few hundred feet up is usually more polluted with solids than is ground level air.

- "Some Applications of Lasers in Atmospheric Studies Atmospheric Environment." Pergamon Press, 1967, Vol. 1, pp. 341-344.

A "research note" summarizing the interests of eleven groups—principally in the United Kingdom who were using or were planning to use lasers to study the atmosphere.

- (1) Mr. R. T. H. Collis (Stanford Research Institute). The lidar units built at Stanford and their value in cloud study are described. Lidar can measure cloud base when bad weather keeps most other ceilometers from operating.
- (2) Mr. L. G. Bird (Meteorological Office). Lidar equipment used for measuring cloud heights are discussed.

- (3) **Mr. C. Spragus (RAE, Aberporth).** The use of lasers in the measurement of wind profile, cloud base and slant visibilities in predicting rocket courses was being considered.
- (4) **Mr. M. C. W. Sandford (Radio and Space Research Station, Slough).** Optical radar soundings of the upper atmosphere.
- (5) **Mr. K. Marsh (British Petroleum).** Considerations of using lasers for tracking the invisible effluent from oil refineries.
- (6) **Mr. D. E. Killick (Radio Department, R. A. E. Farnborough).** This group is interested in applying lasers in atmospheric transmission and airborne solar spectroscopy.
- (7) **Dr. S. R. Craxford (Warren Spring Laboratory).** Interested in monitoring the mixing layer over cities as part of their study of urban pollution.
- (8) **Mr. W. R. Lane (C. D. E. E. PORTON).** Interested in and investigating the use of a lidar system to study characteristics of the radiation back scattered from particles in the atmosphere.
- (9) **Dr. P. M. Hamilton (Central Electricity Research Laboratories, Leatherhead).** Lidar equipment has been used for over a year to study the rise and dispersion of chimney plumes from two power stations. Lidar, as well as measuring the rise and extent of the plume, can also contribute to knowledge of thermal structure necessary to understand plume behaviors and the distribution of particles in the plume.
- (10) **Dr. P. J. Bateman (Ministry of Aviation, R. A. E., Farnborough).** A theoretical and experimental study on the use of pulsed laser beams for atmospheric studies is discussed. The effects that atmospheric turbulence and scattering would have on the laser beam are listed.
- (11) **Mr. C. A. Small (Trinity House).** The laser is being considered for use in detecting fog banks from a distance.

The Integrating Nephelometer

Ahlquist, N. C., R. J. Charlson. "Monitoring of Atmospheric Aerosol Parameters with the Integrating Nephelometer." *Journal of the Air Pollution Control Association*, Vol. 19, No. 12, pp. 937-942, Dec. 1969.

The work done to date with the integrating nephelometer is summarized. The points discussed are (1) design and operation of the instrument, (2) calibration, (3) correlation of nephelometer output with mass concentration, (4) correlation of nephelometer output with visual range, (5) the wavelength dependent nephelometer and the regularity of the color of haze, (6) application of the integrating nephelometer to the mobile reconnaissance of aerosols.

Ahlquist, N. C., R. J. Charlson. "A New Instrument for Evaluating the Visual Quality of Air." *Journal of the Air Pollution Control Association*, Vol. 17, No. 7, July 1967, p. 467.

This paper describes the integrating nephelometer in detail. The instrument is used in measuring the light scattering coefficient of air which is related to visual quality of air. A block diagram is shown and all components of the nephelometer are described. The method of operation is discussed and preliminary data from two observations is presented.

Charlson, R. J., H. Horvath, R. F. Pueschel. "The Direct Measurement of Atmospheric Light Scattering Coefficient for Studies of Visibility and Pollution." *Atmospheric Environment*, Pergamon Press, Vol. 1, No. 4, July 1967, p. 469.

The integrating nephelometer is discussed in detail. A history of the instrument is given. A block diagram of it is shown with all components listed. The different components are described and the operation of the instrument is discussed. The integrating nephelometer is a rugged, inexpensive, portable, lensless system which can measure the light scattering coefficient of aerosol particles in air. The significance of the light scattering coefficient to visibility and the relationship of the scattering coefficient to the mass of suspended particulate matter is discussed.

Horvath, H., K. E. Noll. "The Relationship Between Atmospheric Light Scattering Coefficient and Visibility." *Atmospheric Environment*, Vol. 3, pp. 543-552, 1969.

The determination of the relationship in the atmosphere between visibility and the apparent scattering coefficient as measured by an integrating nephelometer is discussed.

The Non-Dispersive Infrared Analyzer

Peterson, C. O., Jr., W. V. Daily, W. G. Amrhein "Applying Non-Dispersive Infrared to Analyze Polluted Stack Gases." *Instrumentation Technology*, Vol. 14, Aug. 1967, pp. 45-48.

The non-dispersive infrared analyzer which can be sensitized to measure a highly corrosive, reactive gas (nitrogen dioxide) in the parts per million range is discussed. A non-dispersive infrared analyzer with a negative type filter rather than a positive type is used. It is sensitized at the infrared region of interest to read only the emissions of the component desired. Background components are transparent. Both types of filters and the principles of the technique, equipment used, and methods are discussed in detail.

The Optical Interferometer

Bessen, A., "Pattern-Recognition Logic Analyzes Infrared Signals." *Electronics*, Vol. 41, No. 23, p. 112, Nov. 11, 1968.

A prototype pollution detector is described which used an optical interferometer, but can identify several contaminants without changing optics because its filtering and logic enable it to discriminate among those with similar logic. The optical interferometer periodically scans a wide range of the infrared spectrum and detects traces of gases, vapors, and aerosols that absorb energy in this system. The resulting signal is processed using Fourier-transform and decision-theory methods. The analyzer can be tuned to distinguish another set of pollutants by simply changing the logic cards.

Computerized Air Monitoring Systems

Brodovicz, B. A., Jr., V. H. Sussman, "Pennsylvania's Computerized Air Monitoring System." *Journal of the Air Pollution Control Association*, Vol. 19, No. 7, July 1969.

The air monitoring network, when completed is to include approximately 25 remote stations. Each remote station will contain air pollution and meteorological sensors, signal conditioning equipment, and circuits to telemeter information to a central station which features computer control in combination with output options. The basic components of the station are telemetry and control scaling and conversion, and computation and output.

— "Automated Integrated Air Pollution Sensing and Data Acquisition System in Operation in New York City." *Chemical Engineering Process*, Vol. 65, No. 1, p. 100, Jan. 1969.

This system, put into operation in New York City, incorporates a computer-controlled central recording station, 10 automatic remote data acquisition facilities located at strategic sites throughout the city and peripheral

equipment for manual control, printout and data analysis of critical air pollution parameters. The ten automatic stations of the New York Aerometric Data Acquisition System use conventional analyzers for continuous monitoring of three air pollutants—sulfur dioxide, carbon monoxide, and small airborne particles. Also continuously measured are wind direction, wind velocity, and air temperature. The system can be enlarged to thirty stations, each accommodating up to sixteen sensors. One of the present stations also measures radiation.

Miscellaneous

Charlson, R. J., N. C. Ahlquist, H. Horvath, "On the Generality of Correlation of Atmospheric Aerosol Mass Concentration and Light Scatter." *Atmospheric Environment*, Vol. 2, pp. 455-464, 1968.

Data is presented from a series of simultaneous light scatter-mass concentration measurements in several different locations under a variety of meteorological conditions. Results indicated that (at low humidity) a useful relationship exists between the light scattering coefficient of atmospheric air and the mass concentration of suspended particulate matter or aerosols.

Noll, K. E., P. K. Mueller, M. Imada, "Visibility and Aerosol Concentration in Urban Air." *Atmospheric Environment*, Vol. 2, pp. 465-475, 1968.

A relationship between prevailing visibility and mass concentration in urban air was developed. When the results of 4 investigations were compared they showed that the concentration was inversely proportional to visibility.

WATER POLLUTION

General Remote Sensing of Water Pollution

Chandler, P. B., "Remote Detection of Oil Pollution Within the 8 to 14 Micron Infrared Region." Papers from the 36th Annual Meeting of the American Society of Photogrammetry, p. 405, March 1970.

Work by North American Rockwell has shown that surveillance of oil slicks by means of sophisticated remote sensors such as ultraviolet and infrared scanners, and microwave radiometers, is feasible. Oil slicks in harbors and on the open sea along the southern California coast have been observed by North American Rockwell remote-sensing aircraft utilizing the above mentioned equipment. An 8-14 micron infrared mapper, a 19.35 GHz microwave radiometer, aerial cameras, and a multiband video-system were used. The best definition of oil slicks was within the 8-14 micron thermal infrared region. Oil slicks gave a cold response. The author feels that oil slick volume may be easier to estimate using the 8-14 micron thermal region than by conventional aerial photography, although much work needs to be done to improve the technique.

Hom, L. W., "Remote Sensing of Water Pollution." *Journal of the Water Pollution Control Federation*, Vol. 40, No. 10, Oct. 1968, pp. 1128-1738.

This paper discusses the principles of remote sensing and its applications to Water Pollution detection. Points discussed include a brief history of remote sensing, basic considerations of the electromagnetic spectrum, aerial panchromatic photography and aerial infrared imagery. Also briefly mentioned are the applications to water pollution detection of microwave sensing, airborne magnetics, gamma ray spectrometer, detecting chemical vapors, and fluorescent processes.

Aerial Panchromatic Photography

Scherz, J. P., "Aerial Photography: A Promising Tool for Pollution Control." *Safety Maintenance*, Vol. 135, pp. 33-36, March 1968.

The use of aerial photography as a useful tool in detecting water pollution is discussed. Reflection curves for various wastes were determined. By analyzing these curves it was possible to predict how they would show on different films and which photographic combinations would best detect the wastes. Various films and filters were used that covered the spectral region of interest.

Scherz, J. P., D. R. Graff, W. C. Boyle, "Photographic Characteristics of Water Pollution." *Photogrammetric Engineering*, Vol. 35, No. 1, p. 39, Jan. 1969.

Special aerial photography can be used to advantage in detecting and photographing water pollution. No one film-filter combination is best for all cases. Heat effects are not successfully photographed. Kodak film type 8443 with a No. 36 filter proved best for photographing only the surface of the water. Agfachrome unfiltered film was especially sensitive to the green wavelengths many feet deep in the water. Deep lying weed beds showed up distinctly on the pictures. For photographing municipal waste in the Wisconsin River an unfiltered Kodachrome II film or a Kodak 8443 film with a No. 4 filter worked best.

Waldichuk, M., "Currents From Aerial Photography in Coastal Pollution Studies." (Abstract of a research paper presented at the Third International Conference on Water Pollution Research in Munich, Germany, in September 1966.) *Journal of the Water Pollution Control Federation*, Vol. 38, No. 3, March 1966, p. 394.

Aerial photography has many advantages over the boat technique for mapping pollution because rapid coverage of an entire area can be made, a synoptic picture of the positions of drift material can be obtained, and frequent photographic coverage can be achieved more easily to obtain short period drifts. This paper describes how aerial photography was used to assess the currents in the areas in which two sites for sewer outfalls along the Canadian Pacific Coast were located. Large sheets of paper were used as photographic targets in the vicinity of Victoria. In the Vancouver area, currents could be assessed by looking for outflows of silty fresh water from the Fraser River. These areas appear as intrusions into darker-appearing sea water on the ebbtide.

James, W., F. J. Burgess, "Air Photo Analysis of Ocean Outfall Dispersion." Papers From the 36th Annual Meeting of the American Society of Photogrammetry, p. 559, March 1970.

Aerial photography has potential for being a valuable tool in the study of dispersion of wastes in the ocean and for monitoring waste disposal outfall. This technique presents a method where concentrations throughout the waste field or plume can be measured in one instant, rather than trying to compile data from boat measurements taken over a period of hours in which the concentration is always changing.

Aerial Infrared Imagery

Adams, W., L. Lepley, C. Warren, S. Chang, "Coastal and Urban Surveys with Infrared." *Photogrammetric Engineering*, Vol. 36, No. 2, Feb. 1970, p. 173.

This paper describes infrared remote sensing studies done in Hawaii in which the AGA thermal scanning system "Thermovision" was applied as an airborne remote sensor to map coastal thermal anomalies, possibly correlated with ground-water outflows into ocean water. The equipment and procedures are described. Other uses for "Thermovision" are also discussed. In urban areas, hot air or gas leaks from underground pipelines can be detected, insulative characteristics of building structural materials can be measured. It is also possible to estimate easily water-main breaks, transportation patterns, and land use patterns in real time. "Thermovision" can also be used in the field of forestry and agriculture.

Van Lopik, J. R., G. S. Rambie, A. E. Pressman, "Pollution Surveillance by Non-Contact Infrared Techniques." *Journal of the Water Pollution Control Federation*, Vol. 40, No. 3, p. 425, 1968.

This paper concerns the use of airborne infrared mapping systems in the measurement and delineation of thermal pollution of water and theoretical aspects of non-contact determination of pollutant type, concentration, and distribution. Discussions are focused on the 4-14 micron portion of the infrared spectrum. Specific applications discussed are the capability of rapidly spotting discharge points and surface thermal diffusion patterns such as cold water drainage into a large body of water, and heated effluent discharged by industry into a large body of water. Several photographs are shown in which the thermal differences in the water are quite apparent. Although non-contact infrared techniques determine the temperature of a surface layer only tens of microns in thickness, accuracies of ± 1 or 2 degrees centigrade can be made readily and accuracies of ± 0.2 degree centigrade can be achieved with precision techniques.

Van Lopik, J. R., A. E. Pressman, R. L. Ludlum, "Mapping Pollution with Infrared." *Photogrammetric Engineering*, Vol. 34, No. 6, p. 561, June 1968.

The 8-14 micron band is optimal for most aerial infrared surveys because energy emitted by the earth's surface is at a maximum and atmospheric absorption is at a minimum. An aerial infrared study at Galveston Bay, Texas, is discussed, and pictures are shown which clearly demonstrate the effectiveness of aerial infrared photography.

Radiophase

Barringer, A. R., J. D. McNeill, "Radiophase—A New System of Conductivity Mapping." *Proceedings of the Fifth Symposium on Remote Sensing of Environment*, Sept. 1968, p. 1517.

Radiophase utilizes the signals of ULF radio stations to measure subtle changes in conductivity in the earth down to depths of several hundred meters and is of primary use to geologists. One potential application, however, might be in measuring the extent of water pollution and estuarine salinity by mapping its conductivity.

Earth Resistivity Measurements

Warner, D. L., "Preliminary Field Studies Using Earth Resistivity Measurements for Delineating Zones of Contaminated Ground Water." *Ground Water*, Vol. 7, No. 1, Jan.-Feb. 1969, pp. 9-16.

Electrical resistivity field studies were carried out at five sites on Long Island and three sites in western Texas as a preliminary evaluation of the use of a geophysical method for outlining zones of contaminated ground water where a resistivity contrast exists between contaminated and uncontaminated ground water. Three of five sites tested on Long Island gave partially successful results. At the two other sites variations in topography, variations in soil characteristics, and the presence of buried conductors caused data to be uninterpretable. In the Texas studies, only one produced usable results. Existing field conditions at the other two locations caused those two surveys to be unsuccessful. Although the studies were only partially successful, further effort toward developing electrical resistivity as a method for evaluating variations in ground-water quality is encouraged.

GENERAL REMOTE SENSING AND RESEARCH CENTERS

Badgley, P. C., A. P. Colvocoresses, C. D. Centers, "NASA Earth-Sensing Space Flight Experiments." *Photogrammetric Engineering*, Feb. 1968, Vol. 34, No 2, p. 162.

The Earth Resources Program has tentatively defined a sizable group of instruments for space flight to monitor the Earth's natural and cultural resources by remote sensing from space. Among the potential applications of the earth resources data gathering system are climatic conditions, air pollution, ground water discharge, water pollution effluents of major rivers, thermal conditions, and others relating to other fields. Different types of cameras, film and filters used in two experiments are discussed.

Badgley, P. C., W. L. Vest, "Orbital Remote Sensing and Natural Resources." *Photogrammetric Engineering*, Vol. 32, No. 5, pp. 780-790, Sept. 1966.

This article is primarily a discussion of a program initiated by the National Aeronautics and Space Administration in which remote sensing from satellites is used to aid forestry, geology, geography, and oceanography. Several of the remote sensing devices can be used for pollution studies. Charts are shown which list the equipment used and its applications. For example, in the oceanographic applications, sea surface thermal mapping, water color analyzing, current measurements and others are listed. In the geological study, among geological measurements are climatic conditions, population movements, transportation and linkages, land use and urban studies. Hydrologic applications include ground water discharge, salt content and light absorption of water, water pollution, effluents of major rivers and others.

Metalucci, R. V., M. Abdel-Hady, "Infrared Aerial Surveys in Environmental Engineering." *Proceedings of the American Society of Civil Engineers-Sanitary Engineering Division*, Vol. 94, No. SA6, p. 1071, Dec. 1968.

Some aspects of remote sensing by infrared radiation for water and air pollution studies are discussed. Basic principles related to infrared radiation are examined, i.e., comparisons between infrared radiation photography and imagery, laws of radiation, electromagnetic spectrum, sources of infrared radiation. Several pollution studies are reviewed focusing attention on some of the advantages of infrared radiation aerial surveys for particular problems—detecting sources of water pollution by thermal pattern mapping, locating areas of ground water discharges to surface-water bodies, displaying stream valleys and subsurface water channels, and also to show the location of buried conduit and power lines.

Applications of aerial infrared radiations surveys to air pollution are also discussed, i.e., identifying plumes. Its potential is very promising, but more research is needed in the area of identifying specific gases.

Merifiend, P. M., J. Cronin, L. L. Foshee, S. J. Gawarecki, J. T. Neal, R. E. Stevenson, R. O. Stone, R. S. Williams, "Satellite Imagery of the Earth." *Photogrammetric Engineering*, Vol. 35, No. 7, July 1969, p. 654.

This paper describes the application of space photography to both atmospheric and Earth Sciences. It is most applicable to those problems which require magnitude, repetition, and which can only be viewed from a vantage point of several hundred miles above the Earth's surface. Manned spaceflight photographs have furnished information on sea surface roughness, areas of potential upwelling, and oceanic current systems. Geologic structures such as the San Andreas fault can be viewed as a whole. Infrared satellite imagery provides meteorological and hydrological data and is potentially useful for locating fresh water springs along coastal areas, sources of geothermal power and volcanic activity. The potential applications of spacecraft imagery are boundless.

Rinker, J. N., "Environmental Analysis—A Challenge to the Remote Sensing Community." Papers from the 35th Annual Meeting of the American Society of Photogrammetry, March 9-14, 1969, p. 55.

Some of the problems facing the world as man places an ever-increasing burden of pressure and stress on his environment are discussed. Included are the population explosion, problems caused by technology, food, water and water pollution, atmospheric pollution, waste disposal, and others. Remote sensing of the environment can be one of the greatest aids in environmental analysis. Many of the methods used are discussed.

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The basic principles of remote sensing are discussed and many photographs are shown and discussed as examples of how remote sensing not only aids scientists to better understand the earth but also is an aid in the various scientific fields such as archeology, oceanography, forestry, prospecting, military science, etc. The use of remote sensing to aid pollution detection is only briefly mentioned but the implications of possible uses are worth noting.

— "Aerial Thermal Photography." *Engineering*, Vol. 203, May 5, 1967, p. 726.

The principle of aerial thermal scanning is briefly discussed and two pictures are shown of infrared thermal photography which photographs heat emitted from the objects in view rather than the reflection of sunlight from the object in view as a normal photograph does. A diagram of how the principle works is given. An advantage of thermal photography is that it can be used at night and when visibility is bad. The uses of infrared detectors in other fields are listed.

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