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SURVEILLANCE OF INDUSTRIAL EMISSIONS USING LIDAR TECHNIQUES

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With the growing awareness of the serious environmental impact of certain industrial activity and more stringent regulations on emissions, the need for powerful measurement techniques for air pollutant emission is increasing. Optical remote sensing techniques are particularly advantageous, allowing large-area monitoring and avoiding sample extraction and preparation difficulties. Three-dimensional measurements can be performed with the differential absorption lidar (DIAL) technique. The ability to remotely measure the flux of a certain gas from different sources is particularly useful. This is achieved by combining wind data with a mapping of the concentration distribution in a vertical plane downwind from the source. In this way, diffuse emissions can also be studied and the total pollutant flux from all sources can be measured.

A mobile DIAL remote sensing system has been employed in monitoring of industrial pollutant emissions. Measurements of total atmospheric fluxes of sulphur dioxide and mercury vapour were performed at 9 different Swedish industrial plants within the framework of a control programme commissioned by the Swedish Environmental Protection Agency. SO_2 was monitored at six different kinds of industries. At several of these plants the flux values deduced from the lidar measurements could be compared with measurements made by the companies themselves. Especially interesting studies of the precision of the lidar flux values could be made in situations where only one or a few well-controlled sources were monitored. Direct comparisons could then be made with the flux determined from *in situ* SO_2 monitors and measurements of the gas flow inside the smokestack. These comparisons show that the values from single point sources correlate well, and indicate that lidar can determine the mean flux over some hours with an accuracy of within ±10% during favourable conditions. The accuracy can in some cases be worse than this, since it depends on range, wind conditions, distribution of the plume, and topography of the measurement area. Thus, it is difficult to give a general accuracy for emission values determined by a lidar system, but the sensitivity and accuracy can be estimated for each individual measurement.

A significant advantage of the lidar technique is its ability to measure the flux from several sources, extended sources and diffuse emissions. Fig. 1 shows an example of SO_2 lidar measurements at a metallurgical plant, which contains several different sources. The result of a vertical scan downwind from all the sources is displayed in part a) of the figure. As can be seen, at least three plumes contribute to the total flux. Part b) shows another type of representation which can be made from such a measurement. Here the concentrations are vertically integrated and the resulting vertical column content is copied onto a map of the industrial area. The direction of the scan is indicated by the horizontal axis. Together with the wind direction, this type of figure can be useful in tracking down the sources, especially if measurements are made in various directions during different wind conditions. A comparison was made of the total SO_2 flux deduced from the lidar measurements and from *in situ* measurements made by the company. The latter value is calculated by summing up emission values from six different locations, which are continuously monitored, and values from manual measurements made irregularly at some additional points. The lidar gave on average 30-50% higher values for the total SO_2 emission. This difference is probably due to diffuse emissions, which are not registered in the measurements made by the company.

Within the project, mercury emissions were also monitored at six different plants. One of the major Hg emission sources is the chlor-alkali industry, where a flowing cathode of metallic mercury is often used in an electrolytic cell. Fig. 2 shows the results of a lidar mercury measurement at such a plant. The largest emission source here is the main electrolytic cell building (cell room N), from which mercury is ventilated through openings along the roof. The spreading Hg plume from this building can be seen in the figure, although part of the plume may be undetected since the lower angles in the vertical scan were limited by a nearby building. Closer to the lidar system, a second smaller plume can also be seen, which was not expected. The source of this was found to be a smaller cell house used intermittently, where some construction work was carried out during the measurements. This activity obviously released a large amount of mercury and contributed substantially to the total Hg flux. Estimates of the Hg flux to the atmosphere were made by the company only at the main cell house. This estimate involved measuring the concentration inside the building and determining the air flow from different subsections. A comparison with these data shows that the lidar measurements gave a total flux twice as high as the company's own estimate. A similar study at another chlor-alkali plant gave a lidar value of four times the earlier estimation, although no 'extra' plume was detected here. This substantial difference is surprising, since it is not likely that the lidar overestimates the emission.

In conclusion, the measurements show that the lidar technique can be a very useful method for remote surveillance of industrial emissions, also in unannounced inspections. During the campaigns, measurements were often performed at different industries during subsequent days without long set-up times. One main advantage is the possibility of rapidly measuring the total emission from several sources, including diffuse emission, at an industrial site without any preknowledge of the exact position of the different sources. This ability is quite unique and often makes lidar measurements more cost-effective than the numerous measurements needed with point monitors or long-path absorption techniques to achieve the same result.

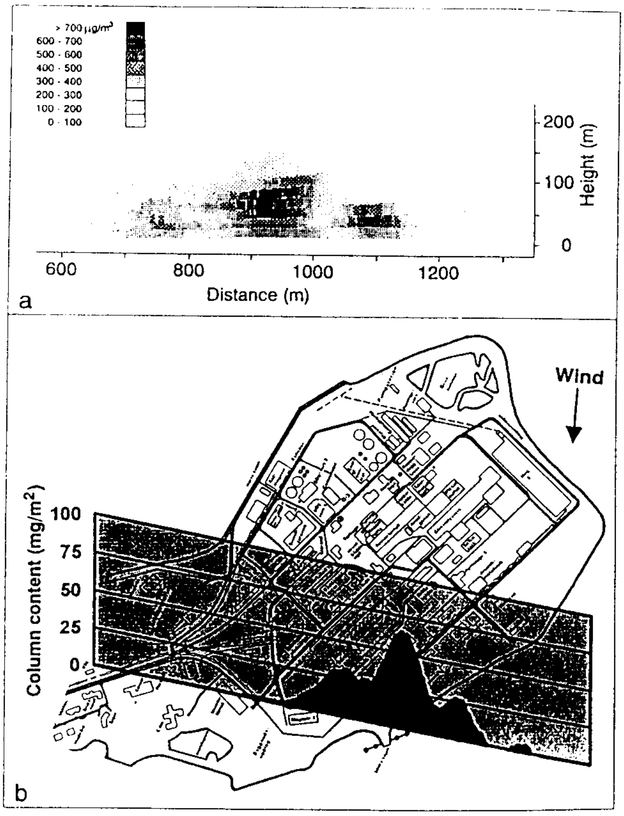

Fig. 1. SO_2 mapping downwind from a metallurgical plant.

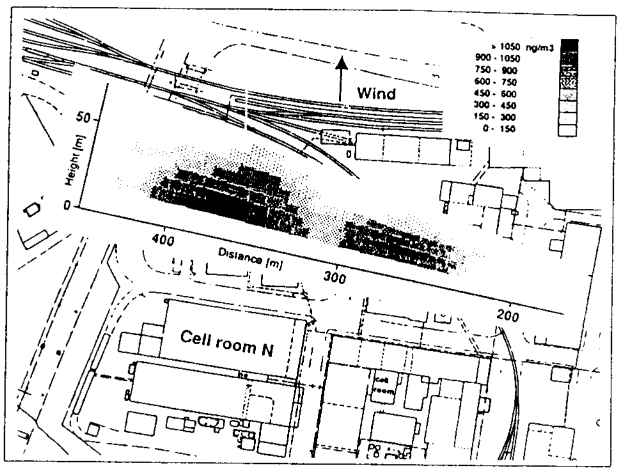

Fig. 2. Mapping of the mercury emissions from a chlor-alkali plant.