NEW METHODS FOR DETERMINATION SO_2 EMISSIONS

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REZUMAT. Protejarea şi conservarea mediului înconjurător este o problemă globală a omenirii. Lucrarea prezintă rezultatele obţinute cu o camera UV şi IR şi compararea cu rezultatele obţinute cu Testo 350 XL. Camera SO_2 este un dispozitiv nou pentru teledetecţia emisiilor centralei electrice folosind radiația solară împrăștiată în atmosferă ca sursă de lumină pentru măsurători. Emisiile de SO2 sunt monitorizate pentru că acest poluant special provoacă efecte foarte periculoase, cum ar fi ploi acide, distrugeri de diferite bunuri, construcţii, şi nu în ultimul rând, cauzează afecţiuni ireversibile asupra sănătății umane. Concluzia lucrării este că, pe baza programului de evaluare elaborat concentrarea datelor furnizate cu ajutorul camerelor UV este adecvată pentru a fi utilizată la măsurarea emisiilor, chiar dacă pentru moment nu exista cea mai bună corelare între emisiile măsurate cu metodele standard, în stivă şi teledetecţia de către camerele UV. Avantajul este nu numai faptul că acestea sunt realizate de la distanţă, fără să aibă nici un amestec cu geometria de aşezare sau alte interferenţe generate, dar şi că acestea pot fi realizate de către orice laborator independent, pentru control şi, de asemenea poate fi folosit ca semnal pentru a suprapune valorile maxim admise.

Cuvinte cheie: camera UV, masa de poluant, teledetecţie, SO2

ABSTRACT. Protecting and preserving the environment is a global problem of mankind. The paper presents the results obtained with UV and IR camera and the comparison with results obtained with Testo 350 XL. The SO_2 camera is a novel device for the remote sensing of power plant emissions using solar radiation scattered in the atmosphere as a light source for the measurements.. SO_2 emissions are monitored as this particular pollutant is causing very dangerous effects such as acid rain, destructions of several goods, constructions, and not at least causing irreversible affection on human health. The conclusion of the paper is that, based on the evaluation program developed SO_2 concentration data delivered using UV cameras are appropriate to be used for stack emission measurements, even it is not, for the moment, accomplished a best correlation between emissions measured with standard methods, in stack, and remote sensing by UV cameras. Their advantage is not only the fact that they are achieved from distance, not having any interference with the stack geometry or generating disturbances, but also that they may be accomplished by any independent laboratory, for controlling and also, used as signal for overlapping maximum admitted values.

Keywords: UV camera, pollutant plume, remote sensing , SO_2

1. INTRODUCTION

The oxidation of sulfur fuel, mostly (95%) is converted into SO_2. Discharged into the atmosphere, sulfur dioxide (SO_2) reacts at a rate of (1-2) $^0/_{00}$ /h with oxygen under the action of solar ultraviolet radiation, creating sulfur dioxide (SO_3).[2] Sulphur dioxide (SO_2) is a toxic substance that attracts attention by its odor and irritating action on mucous membranes, causing muscle spasm and contraction of upper airway. In high concentrations, SO_2 causes irritation and burning sensation of respiratory and conjunctival mucous membranes, cough, difficulty breathing, spasm of glottis, choking. The presence of sulfur oxides in the environment is marked both by direct damage to plants and by altering water and soil composition. SO_2. Thus, in higher concentrations, destroy chlorophyll in leaves, action by amplifying the synergism with NO_2 [3].

SO_2 is widely monitored at power plant. A number of measurement techniques exist, but ever since the first application of the correlation spectrometer. Theoretical description of functionality, applications, and limitations of SO_2 cameras, remote sensing techniques have become more and more established. The method is based on measuring the ultra-violet absorption of SO_2 in a narrow wavelength window around 310 nm by employing a band-pass interference filter and a 2 dimensional UV-sensitive CCD detector. The effect of aerosol scattering can in part be compensated by additionally measuring the incident radiation around 325 nm, where the absorption of SO_2 is about 30 times weaker, thus rendering the method applicable to optically thin plumes. For plumes with high aerosol optical densities, collocation of an additional moderate resolution spectrometer is desirable to enable a correction of radiative transfer effects. This study gives a theoretical basis for the pertinent aspects of working with SO_2 camera systems, including the measurement principle, instrument design, data evaluation and technical applicability. As the dynamic process governing the propagation and dispersal of pollutant plumes in the atmosphere occur on significantly shorter time scales (order of seconds), a simpler and faster means of recording 2-D images of gases is desirable. The large amounts of SO_2 present in power plant plumes and the fact that SO_2 is by far the most dominant absorber around 300 nm, however, make high spectral resolution measurements

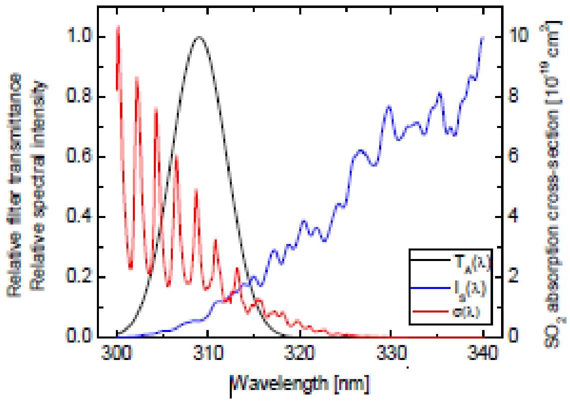

Fig.1. *Example of the spectral transmittance T (λ)*

In this case, the maximum transmittance is centered at 309 nm, a region in which the SO_2 absorption-cross-section σ(λ) is prominent. Also shown in blue is an example spectrum of incident scattered solar radiation $I_S(\lambda)$[1].

Released SO2 reacts to form sulfate aerosol droplets, which back-scatter incident solar radiation, so increasing the albedo of the Earth.

Here, this concept is first dealt with in a theoretical approach. Certain problems are identified, and methods for improving both the accuracy and technical implementation of the technique are described. Finally, some examples of the discussed methods and applications are shown.

2. INSTRUMENT DESCRIPTION

In its simplest form, an SO_2 camera is solely composed of a UV sensitive camera and a single spectral band-pass filter allowing only radiation in a narrow wavelength interval encompassing significant SO_2 absorption structures to enter the camera optics. Figure 1 shows an example of the transmittance curve $T_A(\lambda)$ of such a band-pass filter along with the absorption cross-section σ(λ) of SO_2. For each pixel, the intensity signal collected through this filter is compared to a background intensity, either measured in a region in which no plume is present or interpolated from values acquired on either side of the plume. In the absence of SO_2, the wavelength-dependent light intensity $I_{0,A}(\lambda)$ arriving at each pixel of the 2-D camera CCD is given by the camera measurement.

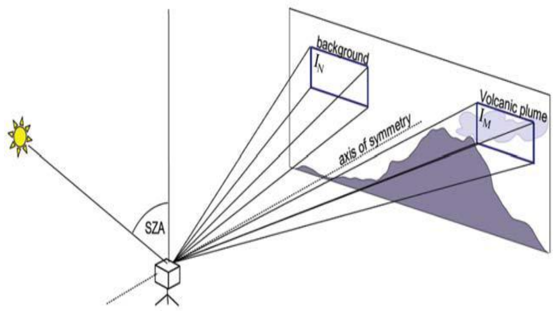

Fig.2. *Geometry of SO_2 camera measurements*

If SO_2 is present in the optical path of the incident radiation, the spectral intensity is attenuated according to the Beer - Lambert-Bouguer law:

$$I_A(\lambda) = I_{0,A}(\lambda) \cdot \exp(-\sigma(\lambda) \cdot S(\lambda)) \quad (2)$$

Here, σ(λ) is the absorption cross-section of SO_2 and S(λ) is its column density, or the integral of the SO_2 concentration along the effective light path L (ideally the line of sight through the plume).

$$S(x) = \int_L c(x)dx \quad (3)$$

Unfortunately, the effective light path L can deviate substantially from the line of sight through the plume. Especially in cases where power plant plumes contain large amounts of SO_2 or scattering aerosols or are viewed from a large distance, the effective light path may be significantly shorter or longer than a straight line through the area of interest. Radiation entering the field of view between the plume and the instrument shortens the effective light path, while multiple scattering inside the plume elongates it. In fact, the absorption of radiation by SO_2 in pollutant plumes is often times sufficiently strong in itself to influence the effective light path.[1]

An advanced optical system was designed specifically for the SO_2 camera in an attempt to reduce the illumination angle dependent calibration issues described in schematic of this design. The optical system is composed of two lens groups between which the band-pass interference filter is located. An adjustable aperture is centered in the focal point of the first lens group. The band-pass interference filter is positioned behind this image so that dust or in homogeneities on the filter are not in focus. Behind the filter, a second group of lenses is used to project the virtual image onto the detector. The position of this lens group in relation to the detector and the virtual image can be varied such that the image is exactly scaled to fit the detector. The great advantage of this setup over the simple setups and shown in is that the angle of incidence λ on the band pass filter no longer varies for individual pixel positions on the detector. Although a range of illumination angles is realized, this range is identical for all pixels, thus leading to an identical effective filter transmission curve.

When selecting the band-pass interference filters for use in the SO_2 camera, several aspects must be considered. Both, the spectral position of the filter transmittance window as well as its width will determine the light throughput of the optical system. This can only be considered an approximation, as very narrow band-pass interference filters tend to have lower maximum transmittances than wider filters, but actual transmittances vary, so this study may represent a somewhat optimistic estimate for narrow filters. Nevertheless, it gives some guidance on how to choose optimal filter parameters.

A camera of the designed SO_2 camera prototype is shown in figure 2. A back-thinned CCD camera was chosen as a detector. Plumes such as this one were intermittently emitted as a consequence of ongoing explosions at this vent.

3 MEASUREMENT CONCEPT

The designed SO_2 camera was tested in several measurement campaigns at power plants in Romania. The concept of measurement is simple. A UV camera is connected to a laptop via USB port and supplied. Once the connection is established a command is give in order to cool camera to -20ºC for eliminating electronic noise. According with meteorological conditions the user can modify exposure time, filters used for measurements, number of measurements, etc.

First a dark measurement is accomplished. After that calibration procedure is did using two SO_2 cells with known concentration and finally background image is did with clear sky. [5]After preliminary settings are made the results are processed and analyzed. The spectrum of scattered radiation arriving at the earth's surface depends on the solar zenith angle (SZA), especially in the UV wavelength region. For high solar zenith angles, the average optical path length through the stratospheric ozone layer is considerably longer than for lower SZAs.9 As the ozone absorption cross-section increases dramatically towards deep UV wavelengths (the lower end of the scattered light spectrum is particularly influenced by these variations in optical path length.

The measurement technique is based on a range of consecutive sequences. Firstly, the dark frame measurement is achieved and then calibration operation is made, using two or more SO_2 cells with known concentrations on a portion with clear sky. Afterwards a clear sky measurement without SO_2 cells mounted was taken, in order to eliminate background noise.[6]

In figure3 are represented a pollutant plumes in UV mode .

Fig 3 *Example of pollutant plume*

4. CONCLUSIONS

The UV camera is a remote sensing instrument for SO_2 measurements and I consider that it will became a very good tool for measurement. Remote sensing technique will became the future option for conventional measurement.

Up to now, UV cameras provided numerous benefits, such as high time resolution, which enables the capture of transient explosive events (such as volcanoes), the possibility to spatially resolve heterogeneous operations, e.g., fumaroles field sources and single-point operations. Furthermore, the camera images can be used to directly measure the plume transport velocity, potentially a major source of uncertainty in these measurements.

The paper focuses on results obtained with UV camera by remote sensing and the comparison with results obtained with stack continuous emission measurements. The conclusion is that both are offering data, but remote sensing is an option that is much more simple to be used, not being connected to the stack and offering thus a mobility and much more accessibility for external monitoring, as well.

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