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CONSTRUCTION OF AN OPTICAL DEVICE FOR MEASURING ATMOSPHERIC DUST EXTINCTION

1. The different behaviours shown by aerosols concerning scattering and absorption, depend on the nature of the aerosols namely, size, size distribution, composition and the meteorological conditions. The aerosols reduce the atmospheric visibility from a few metres to hundreds of kilometres (Waggoner *et al.* 1981). Recently, visibility has been used as a criterion for air quality (Charlson 1969, Fett 1967).

A convenient method to measure the extinction coefficient of light (σ) using optical technique, is described below.

2. *Theory, design and construction of the applied device*

(*i*) When light is passed through a medium of suspended particles, parts of the incident light is dissipated by absorption and scattering, while the remainder is transmitted. The change in the intensity of a plane beam of light in traversing a column of polydispersed aerosols of length x is given by Lambert's law (Lamberts 1960) :

$$I/I_0=e^{-\sigma x} \quad (1)$$

where, I_0 is the intensity of the incident light,

I is the intensity of the transmitted light,

σ is the extinction coefficient of the medium,

x is the path length of the incident light.

Since in the atmosphere both the aerosols and the air molecules contribute to the attenuation of light, the extinction coefficient of turbid air is written as

$$\sigma=\sigma_p+\sigma_{Rg} \quad (2)$$

where σ_p and σ_{Rg} are the extinction coefficient of the aerosols and air molecules respectvely. For urban air pollution the visual problems are due to extinction primarily by fine particles and not by air molecules (Robinson 1983). Thus in this study, the path length (x) of the incident light through the medium is constant and the extinction coefficient σ can be calculated in terms of the effect of the aerosols concentration in the transmittance I/I_0.

(*ii*) *Design and construction* — The applied device consists of the following parts :

(a) *Metal chamber*

Fig. 1(*a*) shows a geometric diagram for the metal chamber (1). It is made of brass and shaped in the form of a cylinder of radius 5.2 cm, and length 36 cm and supported by two valves (2, 3). The upper valve for inlet of atmospheric air and the lower one for outlet. The cylindcrical shape of the metal chamber was taken in consideration owing to its suitability for the shape of the other components connected to it (*e.g.*, lenses, glass plates and photocell). It has been considered in its given dimension that enough amount of atmospheric air is present inside the chamber during the measurements and that the device can be portable.

(b) The upper end of the metal chamber is tightly closed by a glass plate (4), its circumference is attached to a rubber ring (5). It is joined to a wooden box (6) through a metal joining piece (7). Fig. 1(b) illustrates the components of this box. Its upper part is attached to tungsten filament light source (8). The intensity of this source is changed by a variac. Optical filter (9), movable inside a slit (10), intercepts the light beam coming from the light source.

(c) The lower end of the chamber is tightly closed by a concave lens (11), its circumference is attached to a rubber ring (12). This end is supported by a metal base (13) containing a photocell (14) (selen photoelement, Dr. Lange, Berlin) connected through an electrical wire to a very sensitive (10^{-11} A) digital electrometer (Moddel 616 Keithley Instrument-Inc., Clevland, Ohio). A glass plate (15) attached to a rubber ring (16) is interposed between the lens and the photocell for protection purpose.

Fig. 2 illustrates a schematic diagram for the applied device and its connections.

(*iii*) *Preparation of the device* — More than one factor affect the sensitivity of the readings and consequently the accuracy of the measurements of the applied device, namely, degree of evacuation of the metal chamber, luminance of the light source and wavelength of the incident light. To put the apparatus at the optimum condition, these factors have been studied in the following manner.

(a) *Evacuation of the chamber* — The chamber is tightly closed and was evacuated during different periods of time using a suction pump (Model Corning EEL, England). The reading of the electrometer was recorded at successive evacuation time periods (t_e) for white light at potential difference applied to the light source (v) equals 90 volts. These readings give the intensity of the transmitted light (I). The change in the evacuation time period (t_e) leads to a change in the concentration of the aerosol particles inside the chamber, consequently in the intensity of the transmitted light (I). Fig. (3) represents the relation between I and t_e. From this figure, it is clear that I increases continuously with t_e up to 30 second. Above this time (t_e), the light intensity becomes quasi constant. This means that the evacuation inside the chamber represents the available optimum condition. The manometer reading in this case equals —0.66 bar. Accordingly, t_e = 30 sec is taken as the optimum time of evacuation in our measurements.

(b) *Luminance of the light source* (L) — The effect of the luminance of the light source on the measurements sensitivity has been studied for different wavelengths. Fig. 4, a representative curve, illustrates the change of the electrometer reading as a function of the luminance of the light source at λ = 470 nm. The electrometer reading is taken as a measure of the intensity of the transmitted light before and after the inlet of the atmospheric air in the metal chamber (I_0 and I respectively). The change in luminance of the source was achieved through change of the potential difference (v) applied to the lamp. Accordingly, the values of v were used to indicate the luminance of the light sources. High values of v corresponds to high

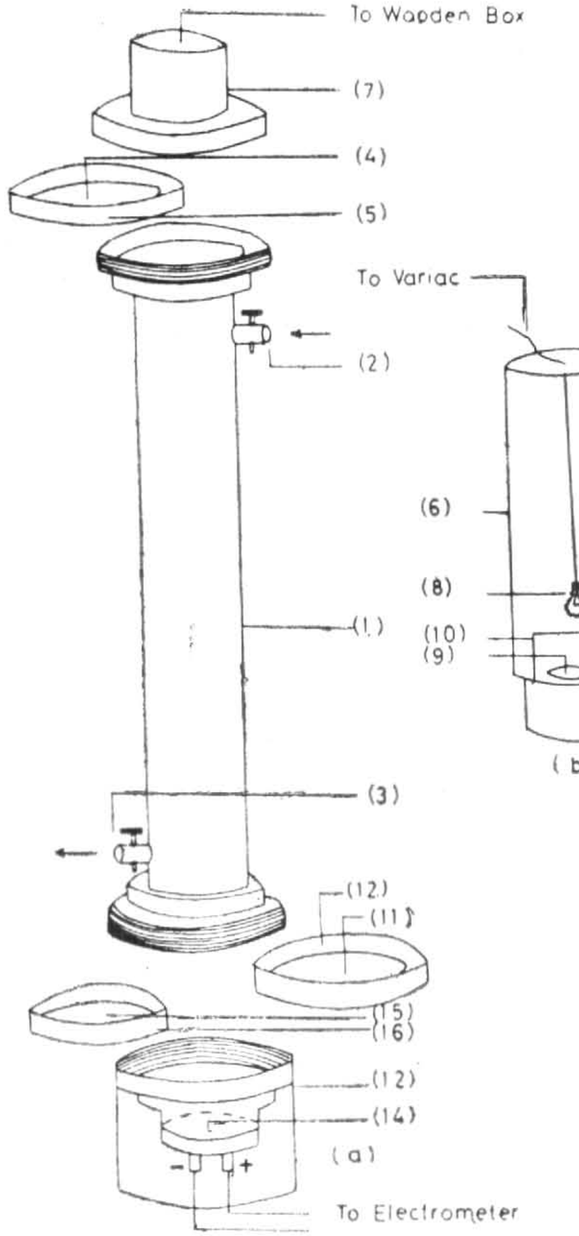

Fig. 1. A geometric diagram of the applied device

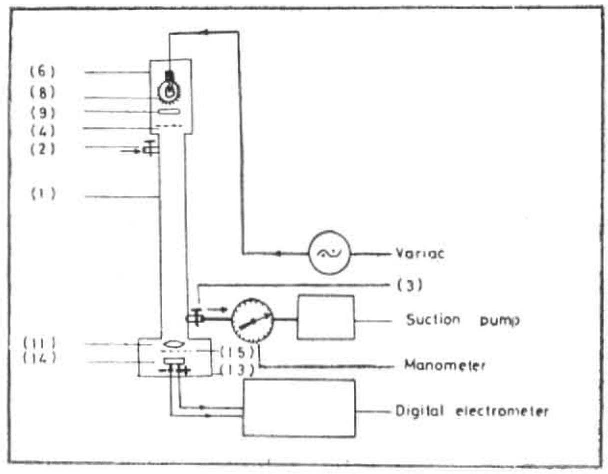

Fig. 2. A schematic diagram of the applied circuit

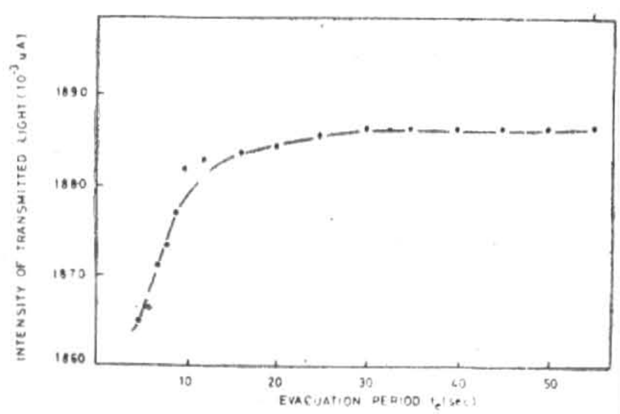

Fig. 3. Intensity of transmitted light as a function of a period of evacuation for visible light at potential difference applied to the light source of 90 volts

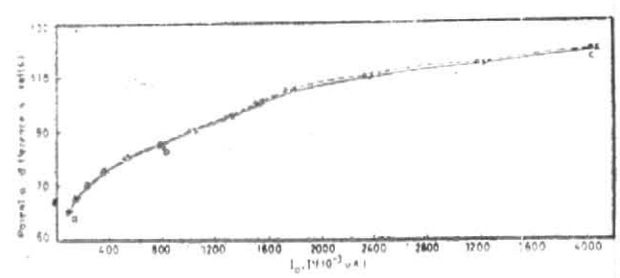

Fig. 4. A representative curve for change of transmitted light intensity before and after inlet of atmospheric air (I_0, I) as a function of potential difference applied to the light source at wavelength of the incident light of 470 nm.

luminance and *vice versa*. From Fig. 4, it is clear that both I_0 and I increase with increasing the luminance of the light source. This increase is slow (part ab) at the voltage range $60 \leqslant v$ (volt) $\leqslant 80$, while it is rapid (part bc) at the range $80 \leqslant v$ (volt) $\leqslant 120$ and it begins to reach a saturation value at $v \geqslant 120$ volts. This behaviour is in accordance with the well known characteristics of the photocell. The figure shows also that acceptable differences between I_0 and I were obtained at voltage range $80 \leqslant v$ (volt) $\leqslant 110$, indicating the high sensitivity of the device in this range compared with these obtained at $60 \leqslant v$ (volt) $\leqslant 80$. Consequently luminance of the light source corresponds to $80 \leqslant v$ (volts) $\leqslant 110$ may be taken as an optimum intensity for sensitive measurements.

(c) *Wavelength of the incident light* (λ) — As a general rule, the best filter to use in a particular determination is that which gives the maximum absorption or minimum transmission for a given concentration of absorbing particles (Bassett *et al.* 1978). Maximum sensitivity is then attained. Fig. 5 represents the transmittance I/I_0 as a function of the wavelength of the incident light λ in nm at the above determined optimum luminance of the light source (110 volts). From this figure the minimum transmittance, which represents the optimum condition of sensitivity, is obtained when filter with $\lambda = 470$ nm has been used. The figure shows also a direct relation between I/I_0 and λ, which leads according to Eqn. (1) to a reverse relation between σ and λ. This results is in a good agreement with others works

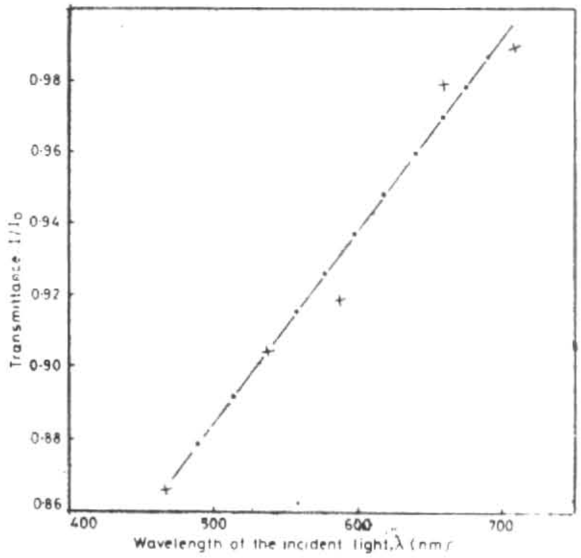

Fig. 5. Transmittance as a function of the wavelength of the incident light at the optimum value of the potential difference applied to the light source (110 volts)

where the most of extinction measurements were carried out also at wavelength around the above value (Waggoner *et al.* 1981, Harrison 1979 and Davies 1975).

(*iv*) *Application* — The device was used to measure the light extinction in the atmosphere of Qena at the determined optimum values (t_e = 30 sec, v = 110 volts and λ = 470 nm). The measurements were carried out on the roof of the faculty of science (about 25 m above the ground) during March 1988. Aerosol particles were collected from the atmosphere on membrane filter (SM 11304) with pore size equal to 0.8 μm using dust sampler (SM 16711). Its concentration in $\mu g/m^3$ is calculated from weight difference between the membrane filter after and before sampling. The extinction coefficient is calculated according to Eqn. (1) through the effect of the aerosol concentration on the transmittance I/I_0. Fig. 6 is a plot of a summary of means of 150 readings of σ against the corresponding total aerosol concentration (c). This figure shows a good correlation ($\approx$ 0.92) between σ & c having a consistant relation with Eqn. (1), since the increasing in c leads to decreasing in transmittance I/I_0 and then σ increases. According to Koschmeider's theory (Koschmeider 1924) which has been summarized by Middleton (Middleton 1968), the well known equation relating the visual range L to the extinction coefficient σ has been derived (Garland and Rae 1970) in the form :

$$L = 3.912/\sigma \tag{3}$$

Using Eqn. (3) the visual range in the atmosphere of Qena has been calculated. It was found to be equal to 127 km. This lies within the range of the meteorological value taken from A.R. Met. Dep. which is about 115 km.

The device has several applications for studying different optical properties of aerosols.

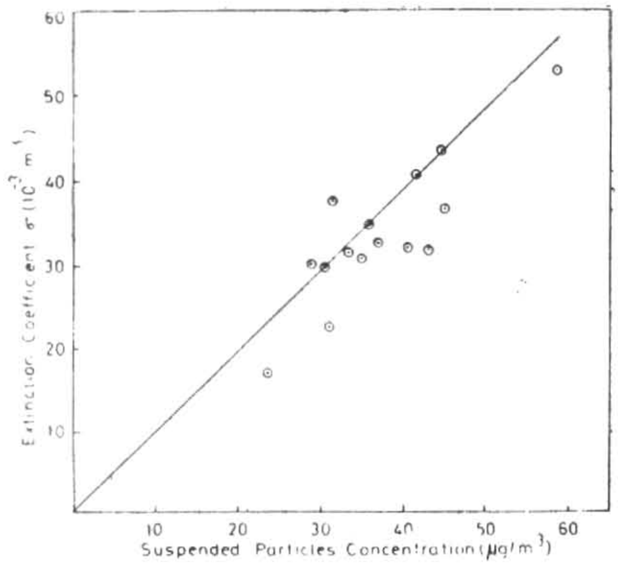

Fig. 6. Plot of average of 150 readings of particle extinction *vs* total suspended particles concentration during March 1988 in the atmosphere of Qena

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1 March 1989