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A short review on the effects of aerosols on visibility impairment

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Abstract. Ozone in the lower planetary boundary layer of the earth atmosphere is dangerous to people and vegetation, since it oxidizes natural tissue. The diminished in visibility is because of dispersing of sun based radiation by high convergences of anthropogenic aerosols. Visibility impairment is most prominent at high relative mugginess when the aerosols swell by the take-up of water to expand the cross sectional area for dispersing; this is the wonder known as haze. Haze has become a major air pollution challenge the aviation industry has to cope with in recent time. In this review, two major problems were spotted to be responsible for air disaster in any region of the world. While some developed countries had almost resolved the challenge of visibility impairment by seeking relevant solutions, most developing countries do not have a recovery plan. Therefore, the resolution of this major challenge may be the leverage for most developing nations to draw out a recovery plan.

1. Introduction

The impairment of visibility has a negative role in the aviation and communication industries. For example, the incessant cancellation of flight in airport and the attenuated communication signals which results to poor signal reception. Visibility impairment also has a positive role of reducing heat flux from the sun by the scattering and absorption of visible light [1]. Fine particulate matters from anthropogenic activities in form of suspended particles are dispersed into the lower atmosphere [2]. The transport of the suspended particulates as they relates with other particulates in the atmosphere may be very difficult to explain in clear terms.

There are lots of emphases on the beneficial nature of ozone (O3) in the upper troposphere and lower stratosphere. However, ozone in the lower planetary boundary layer of the earth atmosphere is dangerous to people and vegetation, since it oxidizes human tissues. O3 in the earth surface is created from the oxidation of CO (i.e. the reaction of CO with the hydroxyl radical (•OH)) and hydrocarbons by OH as a secondary reaction of NOx. In thickly populated districts with high discharges of NOx and hydrocarbons, fast O3 generation happens during daylight and result in a surface air contamination issue alluded to as smog [3]. Fuel burning and different exercises of our modern culture are responsible for its discharge into the air. The particular kind of air contamination related with diminished visibility is called "smog". The decrease in visibility is because of scrambling of sun powered radiation by high groupings of anthropogenic vaporizers as appeared in the figure beneath [3]. Dispersing of sun powered radiation by mist concentrates is the primary procedure constraining visibility in the troposphere. Without aerosols our visual range would be around 300 km, restricted by diffusing air atoms. Anthropogenic mist which concentrates in urban regions regularly lessen visibility by one order of magnitude relative to unpolluted conditions [4]. Debasement of visibility by anthropogenic aerosols is additionally a significant issue in numerous urban region of the developed

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world. The physics of haze is accomplished when the visibility decrease is most noteworthy at high relative humidity when the aerosols take-up water and increase its cross-sectional area for dissipating light.

2. The Physics of Visibility Impairment

The sun illuminates sight path (Figure 1), the atmosphere in the intervening path interferes with the light through the intervention of particulates-mostly aerosols and gases. The particulates affect visibility as shown in Figures 1a & b. The physics of visibility impairment is shown in Figure 1c. The incident multiple light strand from the sun are scattered by the particulates in the atmosphere. This occurrence leads to a diminishing contrast and subdues colours. The remaining absorbed light gives the scene a grayish cast which is seen as visibility impairment (Figure 1b). The collective participation of atmospheric particles and gases to the absorption and scattering are somewhat difficult to estimate. The extension of this major challenge by extension is responsible for signal attenuation in the atmosphere. Particles or gas do not scatter light uniformly in all directions (as shown in Figure 1c) because of its angle-dependent nature [5] and its size.

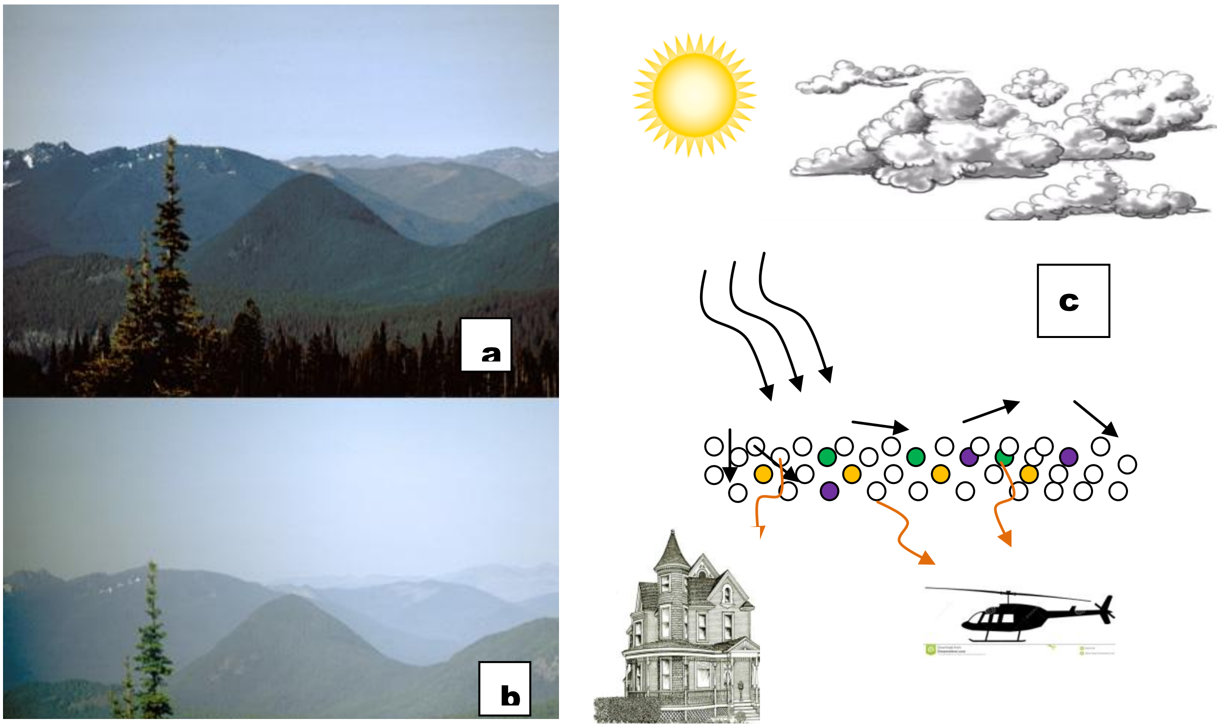

Figure 1. The physics of visibility impairment

The physics of visibility impairment is hinged on couple of physical quantities. For example, Horvath [6] showed that it dependent on the distance from the source of pollution. The minimum distance given was within the range of 50–100km away from the pollution source. This means that visibility impairment over a large geographical area is a result of a multi-faceted pollution sources that eject a large concentration of pollutants. By inference, a densely populated region like Lagos-Nigeria is expected to eject a large volume of anthropogenic air pollution that is expected to affect the visibility of the area. The second parameter that could affect the physics of visibility impairment is the wind speed [7, 8]. Based upon an in-depth study carried out on the wind stagnation parameters over Ota-Nigeria [9], it easy to infer that when there is high wind stagnation, a high visibility impairment is expected. The size of the atmospheric particles and gas over a geographical area can impact upon the visibility. Tsai et al. [10] observed that the visibility variation in Kaohsiung was as a result of the varying sizes of the PM10 (particulate matter of diameter, Dpo10 mm). The varying sizes per time simple means that there would be diverse scattering and absorption mechanism which increases the gray colouration of the particles and gas to increase the visibility impairment. As explained in this section, the number of participating particles and gas in atmosphere may be difficult to estimate. Scientifically, the rough estimation can be obtained from the calculation of scattering coefficient in the lower atmosphere. However, the influence of day and night over the scattering coefficient makes it dynamic in nature. For example, scattering coefficient is influenced by atmospheric temperature and chemical composition [11]. Hence, an increase in the scattering coefficient leads to a reduced visibility. This feat was achieved in UK as a result on the policy on the use of clean energy sources since 1973 [12].

3. Visibility Impairment And The Meteorological Influence

In southern Taiwan, Tsai [10] observed from forty-two years data set (1961–2003) that July which happens to be the hottest month with an average temperature of 29.3 1C has highest average visibility at 17.7 km. It was also observed that the visibility influenced by annual rainfall could increase averagely by 5.94%. The influence of rainy and non-rainy period is further expressed in Figure 2 below.

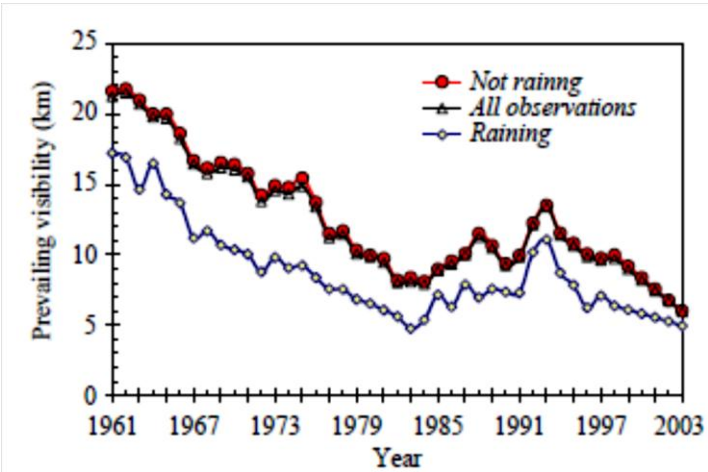

Figure 2. Mean annual visibilities in Tainan between 1961–2003 [10]

The meteorological influence on the lower atmosphere is enormous largely due to massive updrafts and downpour over a geographical location. It affects the height of the mixing layer in the lower atmosphere. The mixing layer of the lower atmosphere affects the diffusion of pollutants in the atmosphere, as well as the ozone concentration [13]. The mixing layer height is influenced by the wind speed changes which affect the dispersion of pollutants [14, 15]. Hence the proximity of Sahara desert and the dust winds over West Africa plays salient role in the visibility state of its member state. The additional anthropogenic emission over West Africa accounts for over 17.6% variance on the ozone [13]. The atmospheric particles and gas dictates the tropospheric ozone as shown over China in Figure 3. Recall that tropospheric ozone formation takes place when nitrogen oxides (from nitrates aerosols), carbon monoxide (from carbon based aerosols) and volatile organic compounds react in the atmosphere in the presence of sunlight. This is a further proof that air pollutant concentration dictates the changes in regional meteorology by the formation of tropospheric ozone via slow-moving, high-pressure weather systems [16].

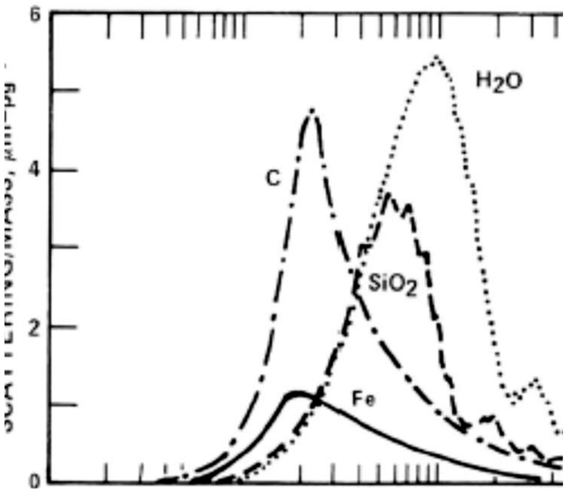

Figure 3. Particles and gas scattering potentials in the atmosphere [17]

4. Mitigating Air Disaster: The Theories Of Visibility Impairment

When there is visibility impairment, pilots rely on the run-way lightning and airport control tower to ensure successful landing. The airport control tower makes use of embedded mathematical software which obeys the Allard's law, Meteorological Optical Range and Koschmeiders's law to calculate the run-way visual range (RVR) amongst other to assist aviation tarmac operations. While the Allard's law predicts the visual range of self-luminous targets, meteorological optical range estimates the length of the path of the luminous flux in the atmosphere and Koschmeiders's law illustrate the connection per time between the inherent luminance contrast and the apparent luminance contrast of an object. The Allard's law and Meteorological Optical Range can be simplified in equations 1 & 2 respectively:

$$E = \frac{Ie^{-\sigma R}}{R^2} \tag{1}$$

where I is the intensity of the run-way lamp, σ is the extinction coefficient, and R is the distance from the lamp. σ is estimated by transmissometers, I is estimated by using the TMS photometrics.

$$MOR = -\frac{\log(0.05)}{\sigma} \approx \frac{3}{\sigma} \tag{2}$$

Though there are proven RVR algorithms used in the aviation sector, the reality of moving layers of aerosols [15] and the collective effect on visibility impairment cast upon the pilot and the operator in the control tower may be dangerous (Figure 4). Hence, scientist had suggested slant visual range (SVR). It is suggested that it is a better gauge of safe landings than VRV. However, measuring the SVR may be very difficult based on the relative motions of the aerosols layer and the path of sight. Hence, this is a major problem in the aviation industry.

5. Conclusion

In this review, two major problems were spotted to be responsible for air disaster in any region of the world. While some developed countries had almost resolved the challenge of visibility impairment by seeking relevant solutions, most developing countries do not have a recovery plan. Therefore, the resolution of this major challenge may be the leverage for most developing nations to draw out a recovery plan.

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