Effects of the Environment

Notes of a Lecture
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Guarding cultural property is one of the prime roles of the museum, and the conservator is guardian against deterioration. There are two kinds of conservation: repair and preventive conservation. Though the former comes first historically, "prevention is better than cure". We have to consider the potentially damaging effects of: visible light and ultraviolet radiation (U.V.); uncontrolled humidity variation; air pollution; temperature.

Biodeterioration, in which we may include the damage caused by man himself, though of great importance, forms a separate subject.

Damage by U.V. Light

All organic surfaces can be damaged by light. The human skin is destroyed by sunlight, but is self-healing (Fig. 1). The surface of museum exhibits cannot be replaced. The most obvious effect of damage by light is a change in colour. An equally important but more insidious effect is the weakening of the support for the colour, e.g. textile fibres.

Figure 1. The effect of sunlight on organic surfaces.

Some patches on the multi-coloured curtain in Figure 2 have changed colour. On others the colour is unchanged, while the fabric has been weakened by light energy absorbed by the dye and passed to the fibres. Note that maximum damage occurs on the edge turned towards the light, and that weakening may not be apparent (as in this case) until the fabric is cleaned.

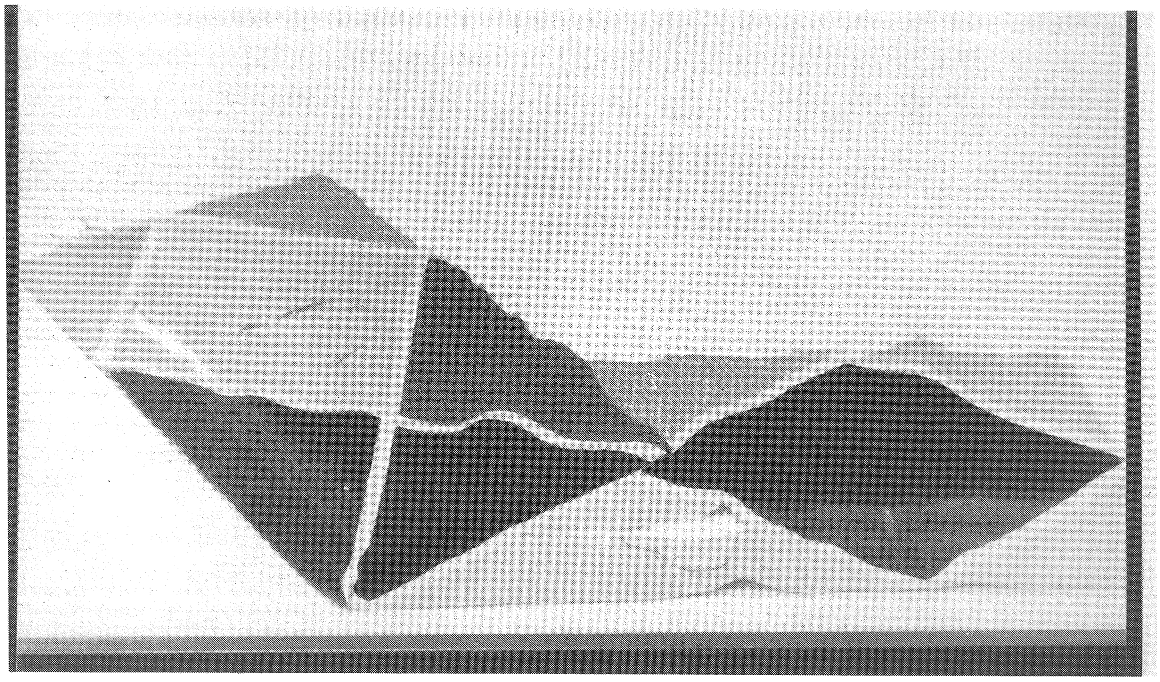

Figure 2. A partly faded and weakened curtain.

Everybody is familiar with the colour changes which occur on textiles, tapestries, carpets, miniatures, natural-history exhibits and watercolours. Consequently one would not expect to see the works of the two greatest watercolour artists of the world, Ma Yuan (Fig. 3) and Turner (Fig. 4) exhibited in strong light. But great changes have also occurred in oil paintings, traditionally regarded as pretty stable.

Figure 3. Ma Yüan, Ink on silk. China, about 1220 A.D.

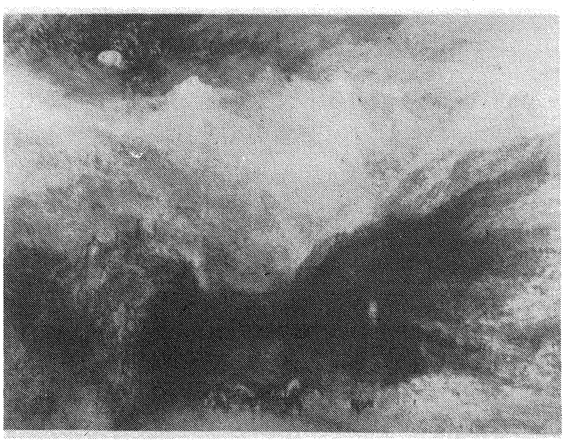

Figure 4. Turner (1775-1851), "Lake of Brienz". Watercolour, Victoria and Albert Museum.

Sometimes the masking of an edge of the painting by its frame protects it from damage by light, thus revealing the damage caused to the exposed paint (Figs. 5-7). Many other colour changes which would have passed unnoticed, such as the colour of a robe, have been detected by analysis, but cannot be shown here without colour.

Modern architecture has not been kind to conservation. Large sun-facing windows, glass walls and batteries of fluorescent lamps all contribute to the acceleration of damage (Figs. 8-11).

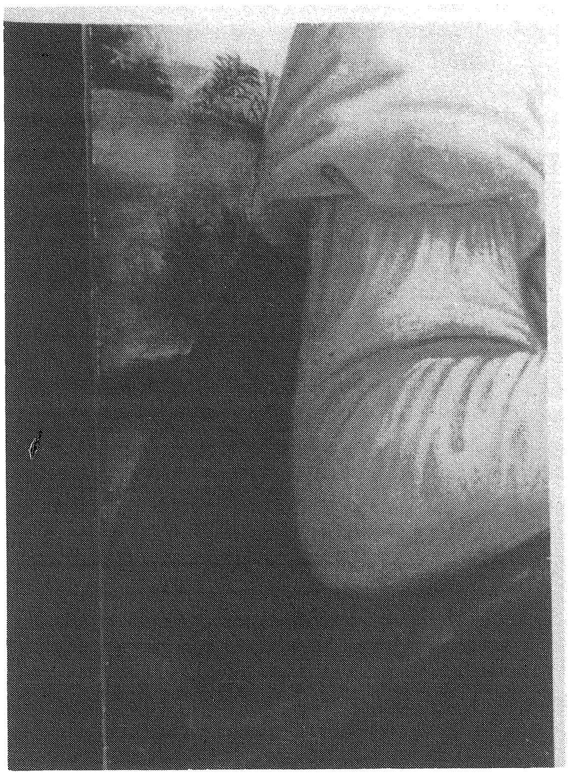

Figure 5. Detail from the edge of a "Madonna and Child" by Signorelli (1441-1523). The frame has protected half of a small plant from the light, so that it has remained green. The exposed half has turned opaque brown. Pigment: copper resinate. By courtesy of the Walker Art Gallery, Liverpool.

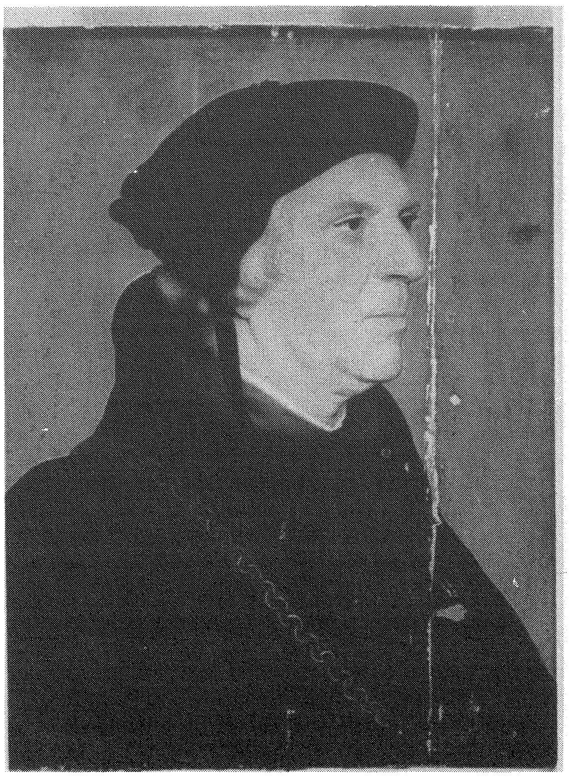

Figure 6. Studio of Holbein, portrait of Thomas Butts. The background pigment, indigo, has faded to a cool grey except where protected by the frame.

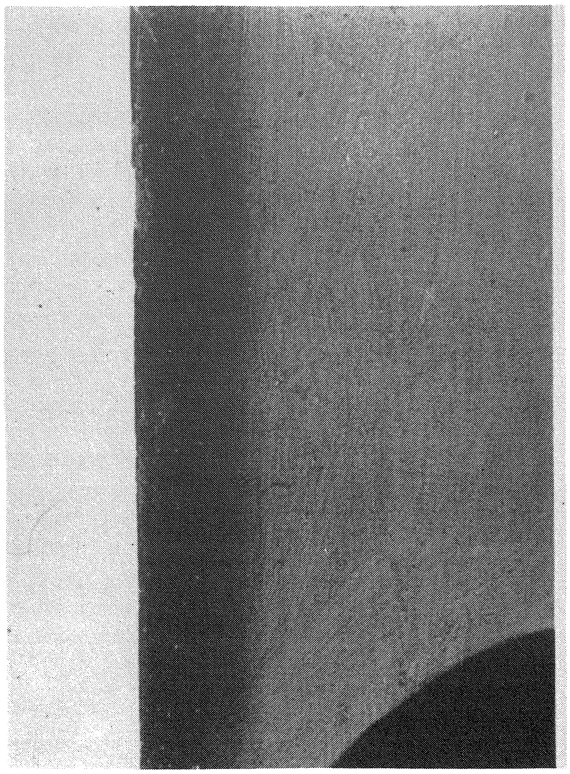

Figure 7. Detail of left edge of Figure 6 showing protection of edge by frame.

Figure 8. South-facing wall of the Pigorini Ethnographic Museum, Rome.

Figure 9. The Guggenheim Museum, New York, by Frank Lloyd Wright.

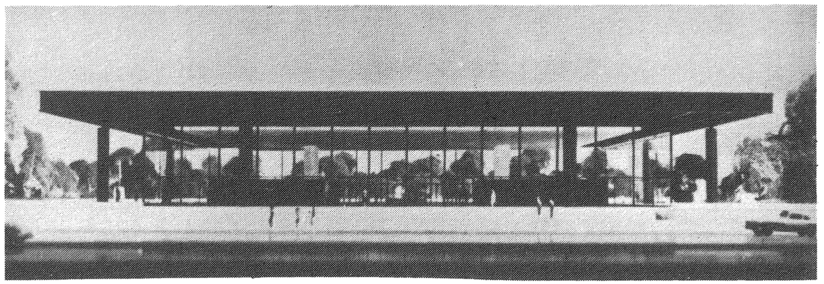

Figure 10. The New National Gallery in Berlin, by Mies van der Rohe.

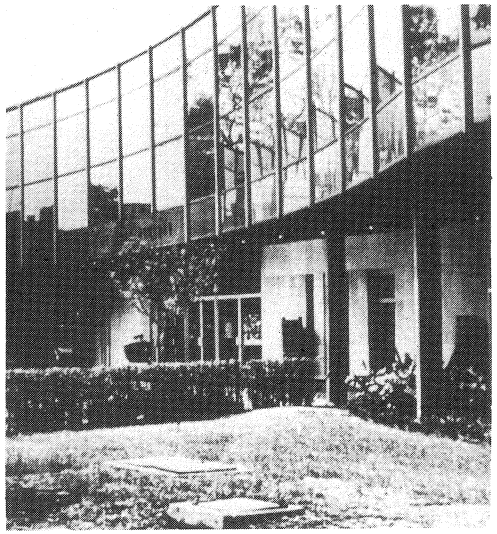

Figure 11. The Museum of Modern Art in Mexico City, by Pedro Ramirez Vasquez.

Damage by Uncontrolled Humidity

If humidity is too high (above 65-70% R.H.), moulds will grow (Fig. 12). Even oil paint is not immune (Fig. 13). If the humidity is too low (40% R.H. is generally regarded as the danger level), moisture-containing objects will warp and crack (Fig. 14).

All moisture-containing objects (e.g. wood, paper, leather, natural textiles, natural-history exhibits) expand in high humidity (high Relative Humidity, see below) and contract in low. These changes can result in warping, cracking and breakage, since different parts of an object can behave differently. The continual warping of a panel painting is invariably betrayed by the pattern of cracks formed in the paint (Fig. 15). Therefore the moisture-content of the exhibits must be kept as constant as possible. Since the moisture in the objects is controlled by the moisture in the air we must control the air, and for this we need a scale of humidity measurement.

Merely measuring the quantity of water in the air will not do. If we hang a towel in warm air we can dry it, but the same air, with the same amount of water in it, if cooled will re-wet the towel. Our scale of humidity is Relative Humidity (R.H.), which is directly related to the expansion and contraction of moisture-containing materials, and indeed is measured by this effect. For our purposes we can regard it as independent of temperature.

$$\text{R.H.} = \frac{\text{mass of water vapour/unit volume of air}}{\text{mass which would saturate air at same temp.}}$$

(usually expressed as a percentage)

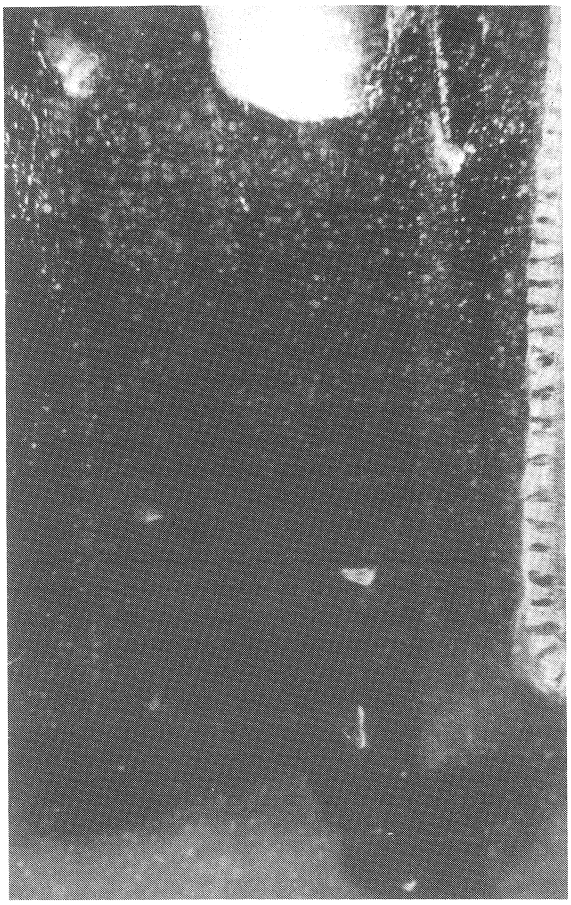

Figure 13. Detail from an oil painting attacked by mould.

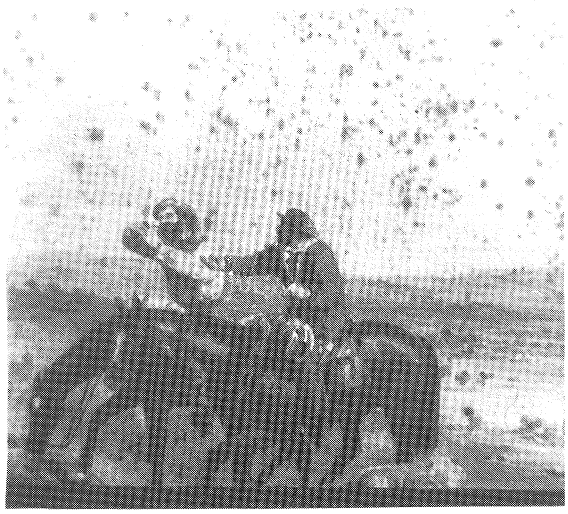

Figure 12. Mould on paper. This and Fig. 13 are from the records of Mr. Ian Cook, Conservator, National Library of Australia.

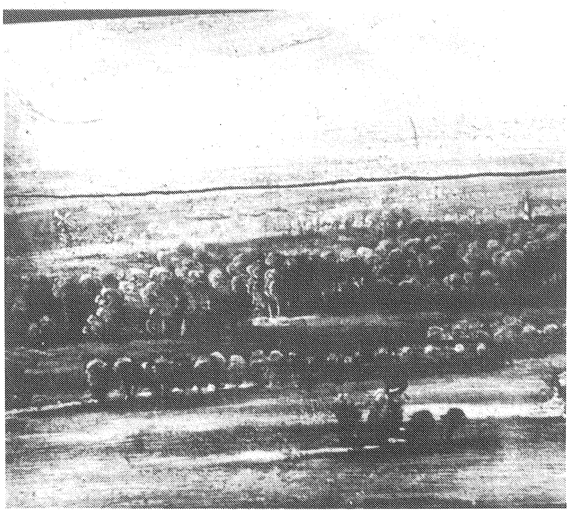

Figure 14. Detail from Rubens' "Chateau de Steen", which many years ago cracked during a period of dry, cold winter weather.

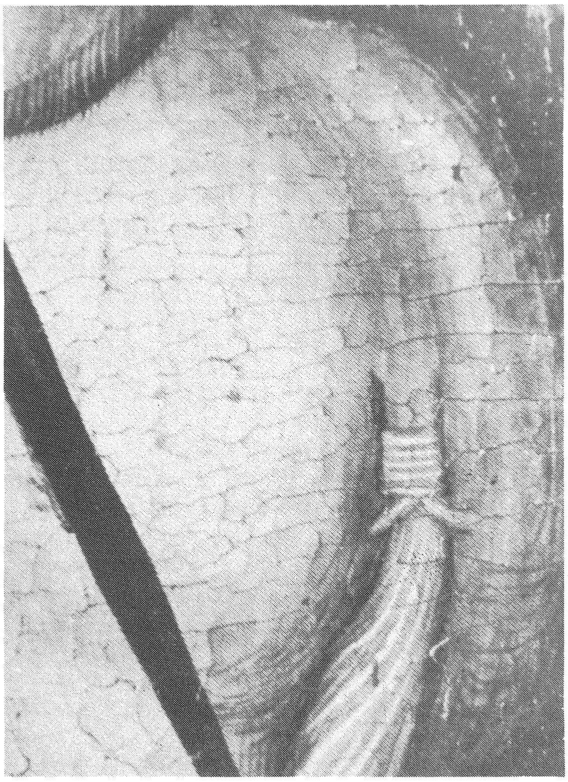

Figure 15. Typical craquelure of a panel painting. (S. Keck, *Studies in Conservation*, 14 (1969), p.22.)

Choice of R.H. level according to climate.

65%	Acceptable for mixed collections in the humid tropics. Too high, however, to ensure stability of iron and chloride-containing bronzes. Air circulation very important.
55%	Widely recommended for paintings, furniture and wooden sculpture in Europe and N. America, and satisfactory for mixed collections. May cause condensation and frosting difficulties in buildings, especially in inland areas of Europe and the northern parts of N. America.
45-50%	A compromise for mixed collections and where condensation may be a problem. May well be the best level for textiles and paper exposed to light.
40-45%	Ideal for metal-only collections. Acceptable for museums in arid zones exhibiting local material.

Figure 16. Choice of R.H. level according to climate.

Our problem will be solved by keeping the R.H. constant, day and night, winter and summer. But at what level? The choice of level is influenced by climate and by type of object, but is limited by the desire to mix exhibits of different material and to loan and borrow from other museums in different climates. In practice we cannot get very far away from 55% R.H. (Fig. 16).

Climate to a conservator can basically be simplified to an R.H. record, since the effects of temperature are very secondary. Meteorological tables (e.g. Met.O.617f Part VI, "Australasia and the South Pacific Ocean", pub. Her Majesty's Stationery Office, London) normally give a monthly average for the early morning R.H., when it is usually at its highest, and also for the mid-afternoon, when it is at its lowest.

We graph the months of the year, starting January, along the x-axis, and the R.H. on the vertical y-axis (Fig. 17). Then, using the average monthly figures for early morning and mid-afternoon, we mark in the high and low R.H. figures, shading in the area between them. For the year this gives a fat line for those months when there is a large diurnal difference, and a thin line when the R.H. is pretty constant through the day. To these mini-diagrams we add lines at 70% and 40% R.H., being the danger limits for mould-growth and embrittlement respectively. Finally in the diagrams is shown the effect of winter heating for those parts of Australia where it is liable to be used. Heating air lowers its R.H., and the effect can be large. The resulting R.H. is shown for the winter period (mid-year) as a patch near or below the 40% R.H. line in the Perth, Adelaide, Canberra, Sydney, Melbourne and Hobart graphs.

These graphs show us at a glance the climatic problems likely to be encountered. In Darwin, Brisbane and Sydney, for example, the R.H. is high enough for long enough to constitute a mould problem. Canberra and Hobart, by contrast, are expected to have the biggest dryness problem during winter heating.

Damage by Air Pollution

The air pollution that is our concern comes from the burning of fossil fuels in factories, power stations, homes and cars, and consists of both solid particles (particulates) and gases.

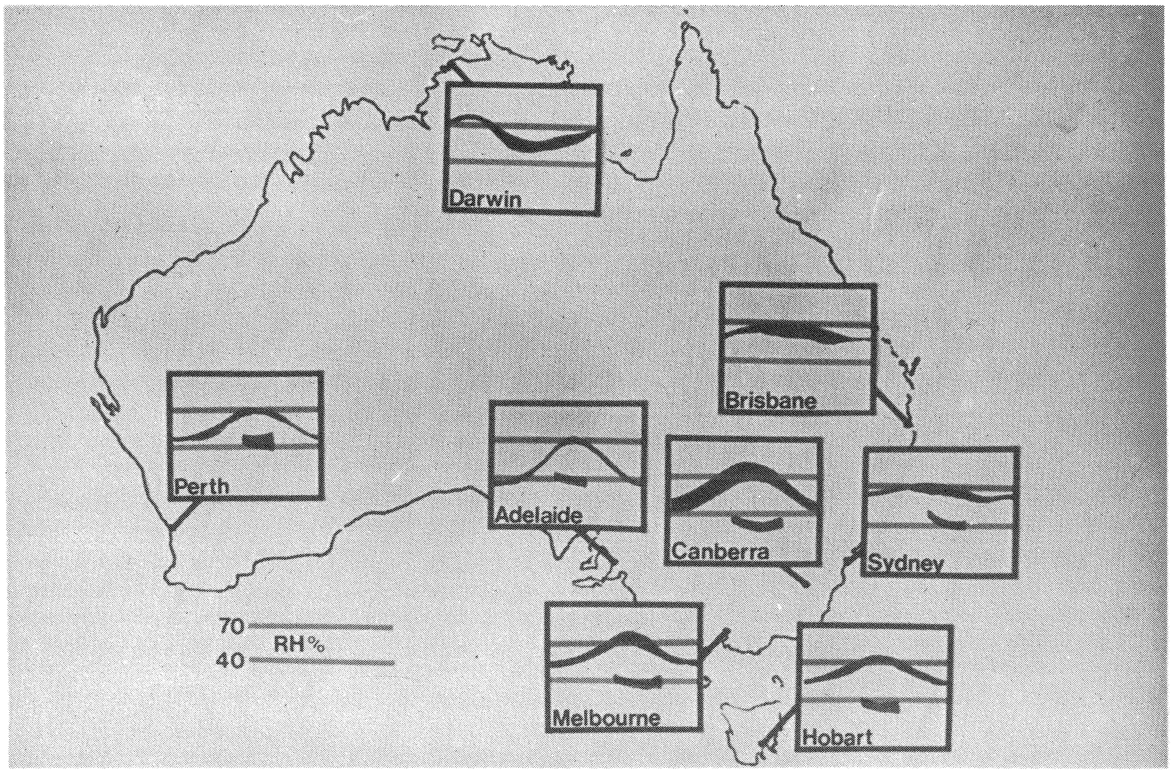

Figure 17. The Conservator's weather map of Australia.

Quantities of both particulates and gases are best expressed in micrograms per cubic meter ($\mu g/m^3$). A microgram is a millionth of a gram. However it will also be found that gas concentrations are quoted in parts per million by volume (ppm) or parts per billion (ppb). Conversion is possible if the molecular weight of the gas is known (for sulphur dioxide this is 64):

$$1 \text{ ppm} = \frac{\text{molecular weight of pollutant gas}}{0.0224} \ \mu g/m^3$$

The air that gets into a non-airconditioned exhibition room in a moderately polluted town is likely to contain 50-100 $\mu g/m^3$ of black tarry particulates. These constitute a hazard since cleaning involves risk. Also the particulates are slightly acid.

All fossil fuels contain sulphur, which during burning is converted to the gas sulphur dioxide (SO_2). SO_2 is readily oxidised, either during its passage through the town air, or after absorption on the exhibit, to SO_3, sulphur trioxide. SO_3 immediately combines with water to form the strong involatile sulphuric acid, H_2SO_4. Sulphuric acid from air pollution has caused great damage to the following classes of cultural property: cellulosics (paper, cotton and linen), proteins (leather, parchment, silk and wool), metals (chiefly iron and steel), and calcareous materials (limestone, marble and murals).

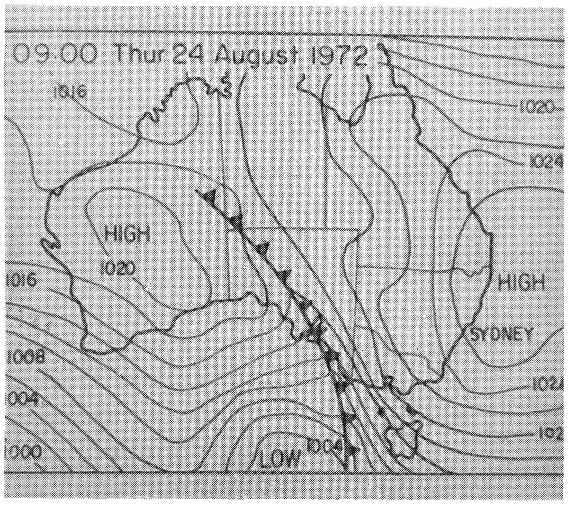

Figure 18. Typical weather conditions for high ozone in Sydney (Hawke & Iverach, *Atmospheric Environment*, 8(1974),602)

A pollutant gas of increasing importance is ozone, O_3. It becomes a potential menace whenever three conditions are fulfilled: (a) A high concentration of cars, as in all modern towns; (b) subshine; (c) still air, or worst of all a temperature inversion which traps air in the city. Further details of the formation of this and other pollutants will be found in Dr Chaston's article. It will suffice here to note that Sydney can get up to 300 $\mu g/m^3$ of ozone (Fig. 18). Ozone attacks all organic materials, accelerating the normal deterioration of their surfaces caused by light and air. In fact it is so reactive that it rapidly disappears in contact with the many organic surfaces of an indoor environment. A test in the National Gallery, London showed that, with outdoor concentrations around 100 $\mu g/m^3$, exhibition rooms, whether air-conditioned or not, nowhere exceeded ½ $\mu g/m^3$.

Electrostatic precipitators (electrofilters) produce small quantities of ozone and are therefore entirely unsuitable as air cleaners for museums.