*Preserving the Astronomical Sky*
*IAU Symposium, Vol. 196, 2001*
*R. J. Cohen and W. T. Sullivan, III, eds.*

# Light Pollution and Energy Loss from Cairo

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**Abstract.** Light pollution is a serious problem, not only to astronomy but also to the environment and the economy. The amount of light energy loss from Cairo has been calculated using data obtained at Kottamia Observatory in 1980 and 1995. The amount of energy loss is much greater in 1995. Comparison with a number of other world cities is given. These results show that much money is being wasted. Recommendations to overcome the problem, and the corresponding savings, are given.

## 1. Introduction

The problem of light pollution and energy loss is one of the important problems to astronomy, the environment and the economy. Many investigators have studied light pollution (see e.g. Walker 1970, 1973, 1977, 1988; Treanor 1973; Berry 1976; Garstang 1984, 1986, 1988, 1991). However, only a limited number of investigators have studied the other face of light pollution, which is the electric energy loss. Hunter et al. (1989) have studied the electric energy loss due to light pollution in the USA. They have found that the total amount of electric energy loss is 17.4 billion kWh per year, costing US$1.288 billion. Isobe and Hamamura (1998) have studied the city lights of Japan observed by the Defense Metreological Satellite Program (DMSP). They have deduced the relative indexes of the cities of Akita, Shizuoka, Hiroshima, Tokushima and Matsuyama. Their results show that the energy loss of city light has increased by 20 to 50 percent in 3 years.

In the present work the effect of light pollution at Kottamia Observatory from the city of Cairo has been studied. Light and electric energy loss for Cairo City estimated from ground observations are compared with space results obtained by DMSP satellites.

## 2. Light Pollution Studies at Kottamia Observatory

The light pollution at Kottamia Observatory from Cairo and nearby cities had been studied during two periods. The first study was carried out by Asaad et al. (1982) at different altitudes in the sky from 5° to 45°. The second set of observations was carried out during Jan-Feb. 1995 over the entire sky and the results have been published by Nawar et al. (1998). The average values are given in Table 1, accompanied by the value obtained in 1980 by Asaad et al. for comparison.

Table 1. Light pollution at Kottamia Observatory in the visual band

| Date | $R$ |
|---|---|
| 12-12-1980 | 0.05 |
| Average of 7 nights in 1995 | 0.49 |

The expected values of light energy loss from Cairo can be estimated by using Walker's relation as follows:

$$\log R = -4.7 - 2.5 \log D + \log F, \tag{1}$$

where $R$ is the ratio between the observed sky glow as measured in the direction of the source and natural background radiation at altitude 45°, $D$ is the distance (in km) between the observatory and the source, and $F$ is the total luminance (in lumen) of the outdoor lighting in the city.

From Walker's relation we can obtain:

$$F = 10^{(4.7+2.5 log D+log R)}. \tag{2}$$

The equivalent electric power loss from the source $E$ in Watts can be calculated as follows:

$$E = F/L, \tag{3}$$

where $L$ is the average lighting efficiency of the source in lumen/Watt. From relations (2) and (3) we can put $E$ in the following form:

$$E = [10^{(4.7+2.5 \log D+\log R)}]/L. \tag{4}$$

If we know $L$ and if we assume the average time for lighting is 10 hours per night during the year, then the average electric energy loss per year ($T_y$) can be calculated as follows:

$$T_y = E(\mathrm{W}) \times 10 \text{ hours} \times 365 \qquad (\mathrm{Wh}), \tag{5}$$

or

$$T_y = C[10^{(4.7+2.5 \log D+\log R)}]/L \qquad (\mathrm{kWh}), \tag{6}$$

where C = 3.65.

From the National Energy Information Centre (EIC) the average lighting efficiency in Cairo is taken as 40 lumen/Watt in 1980 and about 70 lumen/Watt

https://doi.org/10.1017/S0074180900163909 Published online by Cambridge University Press

in 1995. The distance ($D$) from Kottamia Observatory to the centre of Cairo is about 60 km. Then by using relation (6) and the values of $R$ given in Table 1, the equivalent electric energy losses per hour and per year from Cairo in kWh for 1980 and 1995 have been calculated and the results are given in Table 2. The amount of electric energy loss per year from Cairo increased by about 6 times from 1980 to 1995. If we assume that the annual rate of increase of electric energy loss from Cairo is constant, then the expected value of electric energy loss in the year 2000 will be 45 million kWh. Since the average price of 1 kWh of electric energy at Egypt is about US$0.06, then the annual loss per year increased from about US$0.375 million in 1980 to US$2.1 million in 1995.

Table 2. The electric energy loss from Cairo per hour and year

| Date | $E$(kWh) | $T_y$(MkWh) | Loss of Money (Million US dollars) |
|---|---|---|---|
| 12-12-1980 | 1747 | 6.38 | 0.375 |
| Average of 7 nights in 1995 | 9783 | 35.7 | 2.1 |

The light and electric energy loss for Cairo and other capitals in the world using DMSP images (Isobe and Hamamura 2001) have been tabulated in Table 3 for comparison with ground-based observations. It is noticed that the energy loss from Cairo is nearly equal to that of Paris and somewhat lower than that of London, but higher than all the other listed cities. The table shows that the value of energy loss from Cairo obtained from ground-based observations is about 30% higher than that obtained by DMSP satellite images. This difference may be due to atmosphere extinction, the fact that the DMSP measures only the direct light from the city and/or the fact that DMSP measures reflected light which makes a large angle with the horizon (60° to 90°, depending on the sub-satellite track). However, from the ground-based observations we have deduced the total light coming from the city at angles between 0° and 90° with the horizon.

Table 3. Light energy loss from Cairo and other capital cities

| City | Date | Observed Value $10^{-8}$ Watt/cm$^2$/st/ $\mu$m | Light Energy Loss $10^6$ kWh |
|---|---|---|---|
| Cairo | 1997.02.05 | $4.51 \times 10^3$ | 27.00 |
| London | 1997.01.13 | $4.84 \times 10^3$ | 29.00 |
| Amsterdam | 1997.01.13 | $1.07 \times 10^3$ | 6.43 |
| Bruxelles | 1997.01.13 | $9.64 \times 10^2$ | 5.78 |
| Paris | 1997.01.13 | $6.33 \times 10^3$ | 37.90 |
| Tel Aviv-Yafo | 1997.01.09 | $1.72 \times 10^3$ | 10.30 |
| Amman | 1997.01.09 | $8.77 \times 10^2$ | 5.25 |
| Damascus | 1997.01.09 | $4.98 \times 10^2$ | 2.98 |

## 3. Recommendations

So, the following recommendations should be done to overcome the light pollution problem:

1. Set restrictions and laws that require correct light systems.
2. Spread awareness about this kind of pollution among the people via environmental groups.
3. Replace all bad lighting systems with new systems that consume less energy, have a longer life and at the same time give adequate lighting.

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