THE SITUATION OF LIGHT POLLUTION IN GERMANY

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ABSTRACT. We estimate the increase of light pollution in Osnabrück, a town of about 160.000 inhabitants located in northwestern Germany. We try to extrapolate these statistical data to Germany and discuss the reasons for increasing light pollution though the energy consumption nearly stagnates. While the climate in central Europe is not favourable for astronomical research observations in the optical region, the general public looses the unhindered sight of the starry sky. Therefore we present some activities to make the public aware of the problem (e.g. the Astronomy-Online light pollution project) and strategies for reducing artificial night lights.

1. Introduction

The central European climate is not ideal for serious astronomical observations. Though many of the old established astronomical institutes are situated in this region, modern observing facilities are built at places with more favourable climate and less light pollution. Nevertheless astronomical observatories in Germany are used for educating students, testing new equipment and some astronomical research, e.g. at Hamburg-Bergedorf, Potsdam, Bonn, Jena, Heidelberg and Munich. Some observatories are quite far away from disturbing light sources like Wendelstein (Munich), Tautenburg or Hoher List (Bonn) or have arranged reduction of light locally. However thousands of amateur astronomers and millions of other people still have to struggle with light pollution. The experience of planetarians shows that many of their visitors are excited when they see the undisturbed milky way in the planetarium, which might lead to the conclusion that they have not seen it from an unpolluted site before. So the provocative question: Are we on the way to preserve the aspect of the night sky in the planetarium just as we show extinct animals and plants in a natural science museum? Therefore we try to study the increase of light pollution and to find the reasons for this. In addition we discuss projects to make the public sensitive to the problem.

2. Estimating the increase of light pollution in Germany

The best method to measure the increase of light pollution would be measurements of the brightness of sky background. However, these are rare at Germany, even at professional observatories. An indirect method would be the monitoring of the limiting magnitude. As far as we know there exists only a long row of observations from an engaged observer of variable stars in Stuttgart, who observed an increase of the limiting magnitude from

5.6 mag in 1958 to 5.2 mag in 1971 (Marx, 1972), since then the limiting magnitude has increased by about 0.1 to 0.2 mag (Marx, private communication, 1997).
We use another approach: There are many sources that contribute to light pollution, mainly artificial light that is scattered in the atmosphere:

- direct and indirect lights for advertising seem to play a minor role in Germany, because these are restricted, mainly for traffic security reasons. However during the last years sky beamers used mainly by discotheques are increasingly disturbing. These are powerful moving spotlights that sometimes are visible over dozens of kilometers. In several cases even animals (mainly birds, but perhaps also amphibians) have been threatened by these lights.

- direct and indirect lights from private households, e.g. illuminated windows, unshielded garden lighting, continously shining security lights.

- street lighting seems to be the most important contribution, though estimates differ between 14 % (cited by Schreuder, 1991) to 50 % (Shaflik, 1997). In this context the predictions for the increase of outdoor public lighting are especially alarming (Riegel, 1973, Sullivan, 1984). This is much faster than the increase in electricity consumption because more efficient light sources are progressively used. Riegel (1973) estimated that the number ratio of vapor/incandescent lamps in 1960 was about 0.1, in 1970 1.2, afterwards increasing annually by 6 to 10 %. As there was a trend to more efficient high-pressure sodium lamps, the luminous flux increased by 23 % annually between 1967 and 1970.

We want to check if these predictions are also valid for Germany. As it was not possible to get informations about street lighting in the whole country, we have choosen the following way. We compare the relative increase of the public electricity consumption in Osnabrück (Stadtwerke Osnabrück, priv. comm.), Germany and the United States (Bundesministerium für Wirtschaft, 1996) with the values of 1950 (fig. 1). These data have to be judged with caution: electricity consumption in Osnabrück has increased faster because new suburbs are provided with energy. The reunification of Germany changed the electricity consumption in Germany since 1990 significantly. The faster increase in Germany than in the U.S.A. during the sixties might be due to deficits in Germany at that time. The data from Osnabrück and other statistical data show, that street lighting consumes about 1 % of the total electricity ($2.8\ 10^9$ kWh in 1989, alte Länder in western Germany). In the future most lamps used for lighting principal roads will be high pressure sodium lamps. Though low pressure sodium lamps would be more desirable because of their yellow emission lines and higher efficacy, these lamps have difficulties in acceptance due to their bad colour balance. In residential quarters fluorescent lamps will mainly be used, because of their better colour balance and low cost. This mix will result in an efficacy of about 100 lm/W. In figure 1 we have included the increase of night light in the US as given by Sullivan (1984). We compare this to values in Germany with a rough estimate of increasing light efficacies from about 40 lm/W in 1950 to about 90 lm/W in 1990. From this we see, that light pollution from street lighting increases, but less pronounced as the predictions by Riegel (1973), because

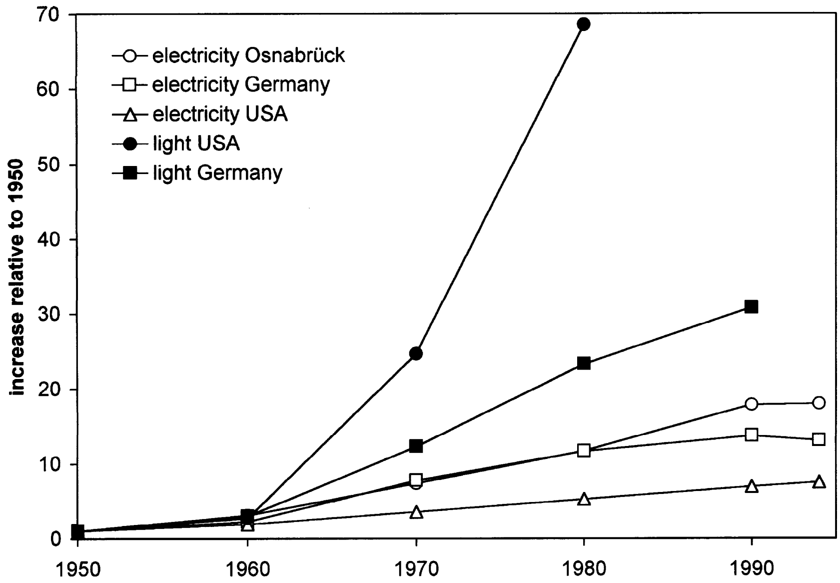

Fig. 1. Annual electricity consumption in U.S.A., Germany and Osnabrück and estimation of the emitted light in the U.S.A. and Germany, normalized to 1950 = 1

energy efficient illumination (mainly fluorescent lamps) has been used in Germany quite early.

For Osnabrück we knew the number of street lamps and the electricity consumption as provided by the local energy company (fig. 2). The number of lamps is steadily increasing, while the power supply and the consumption remain more or less constant. Assuming that during the time interval shown in the graph, the efficacy of the lamps has increased from 80 lm/W (corresponding to a mixture of 50% fluorescent lamps, 40% mercury vapour lamps and 5% sodium lamps) to 100 lm/W (50%:25%:25%), this corresponds nearly to the increase of number of luminaires of about 20%. The reason for this are new residential quarters and the quest for pretended more security through more light. To propagate the reduction of light pollution is the aim of the working group "DARK SKY", which has been formed by some amateur astronomers as a section of the national amateur association *Vereinigung der Sternfreunde*.

3. Aims for reducing light pollution in Germany

The main aim must be the information of the general public, because they are not aware of the problem and ask for more light because they suppose that this gives more security. This is done by information sheets, press releases and talks. This publicity helped to reach some success against the sky beamers. In several cities these have been prohibited, but in others they are still in use. It would be desirable that these light sources become prohibited in general.

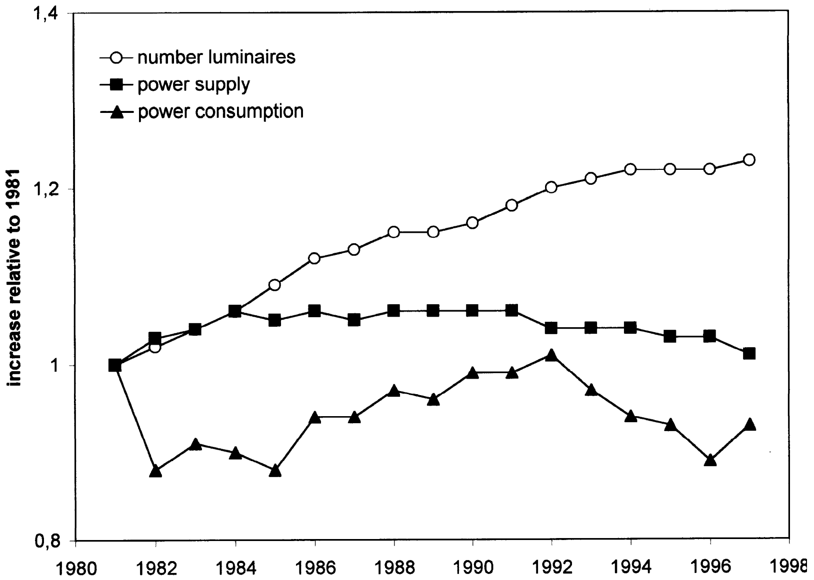

Fig. 2. Number of luminaires, power supply and annually consumed electric energy for illumination in Osnabrück, normalized to 1981 = 1

Most street lighting on main roads is well shielded against the sky. Minimal luminance levels of streets depending on type of street, width and traffic frequency are recommended in norms (Deutsche Industrie-Normen DIN 5044) and these lie between 0.3 and 2 cd/m^2. As traffic frequency reduces during night, the light of some streets is reduced by switching off every second lamp. However, this should be used on more streets. In addition, a trend towards low-pressure sodium lamps instead of high-pressure sodium lamps would also be desirable. Investigations by the Naturschutzbund Deutschland (Schanowski and Späth, 1994) showed that high-pressure mercury lamps attracted and often killed about 4 times more insects than the sodium lamps. Some of the DIN norms are however questionable: why a principal road with identical traffic and passenger frequency within and outside of the limits of a city must be brightly illuminated within these limits and not at all outside? In town centres and in residential areas often badly shielded luminaires are used, where fully shielded luminaires should be preferred. Another aim should be to sensitize the more interested public and especially the youth, which has been tried with the following project.

4. The Astronomy On-Line Project on light pollution

In 1996 the *European Southern Observatory (ESO)* and the *European Association for Astronomy Education (EAAE)* organized the Astronomy On-Line Project to demonstrate the use and advantage of the internet to young people (West and Madsen, 1997). We proposed to measure light pollution in Europe using a simple method to determine the limiting magnitude in the constellation Ursa Minor. The British Sky Glow and the American Star Watch project had inspired us. We wrote a HTML web page with a sky chart that helped to find UMi during the peak phase in November. Another chart gave magnitudes for some stars in UMi to determine the limiting magnitude, which could be reported in a web form. Due to extremely bad weather conditions during the peak phase in Europe only 25 reports mainly from the southern parts of the continent have been received. The limiting magnitude within one city varied considerably, an interesting discovery that pupils in a larger Spanish city and the Bulgarian capital made. The observations together with a weather picture have been posted on the web. Unfortunately more conclusions from the scarce material could not be drawn and it can be hoped that some actual projects in Catalonia and Greece give as interesting results as the Sky Glow project.

5. Outlook

Hunter and Crawford (1991) estimated that in 1985 58 10^9 kWh electric energy have been used for nighttime lighting in the U.S.A., of which about 15 % have been wasted towards the sky due to bad shielding. This corresponds to costs of about US$ 644,000,000. We have compared theses values to similar values for Germany and the city of Osnabrück and compiled them in table 1. Some of these values differ significantly especially between the US and Germany. For Germany and Osnabrück we assumed the same waste to the sky. The amount of the emitted CO_2 depends on the mix of the energy sources for producing the electricity. We used a conversion factor of 1 t CO_2 = 1160 kWh for Osnabrück (Umweltamt, 199?) and 1800 kWh for Germany and assumed the same value for the U.S.. Though the consumption of CO_2 for night lighting is small compared to other human sources of the greenhouse gas, it is an amount that can easily be reduced without losing much comfort. At the 1992 United Nations Conference on Environment and Development in Rio de Janeiro, most industrial nations agreed to reduce their CO_2 production to facilitate a sustainable development in future. This shall be reached with the Agenda 21 action programme. Within this framework the useless waste of nighttime light must be reduced to conserve an unspoiled dark nightsky as far as possible in our modern civilization.

Tab. 1 - Comparison data for the energy of night lighting

annual data	USA (1985)	Germany (1989)	Osnabrück (1989)
total energy consumption kWh	2.3 10^{12}	3.9 10^{11}	7.4 10^8
electricity for nightlight kWh	5.8 10^{10}	2.8 10^9	8 10^6
population	2.5 10^8	6.2 10^7	1.6 10^5
CO_2 t (see text)	4 10^7	1.5 10^6	7 10^3
electricity for nightlight/person kWh	232	45	50
costs US$ (1 US$ = 1.80 DM)	4.3 10^9	6 10^8	7 10^5
15 % wasted US$	6.4 10^8	9 10^7	1 10^5

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