

## Measurement of obtrusive light in terms of Czech Republic

**Abstract.** Obtrusive light (light pollution) refers to both the night sky luminance as well as any light that radiates to the places where it is not required. Moreover, this kind of light increases the energy losses. The measurements are done for the purpose of obtaining information about night sky luminance at different meteorological situations and in different locations. We want to know influence of the artificial light sources on the night sky luminance. Outputs from the measurements are used to verify the physical model of the night sky. The aim of this model is to find out how the artificial light sources (public lighting, or whole cities) are capable to influence the sky luminance at different distances and under different meteorological conditions. The future of this model is to compare influences of the new artificial outdoor lighting systems to the night sky luminance in the project phase.

**Streszczenie.** Przez zanieczyszczenie światłem rozumie się jak oświetlenie nocnego nieba, tak również i każde światło, które oślepia bądź też oświetla miejsca, gdzie światło nie jest potrzebne, co powoduje tzw. interferencję światła. Takie oświetlenie powoduje straty energii. Pomiaru były wykonane dla uzyskania o informacji o jasności nocnego nieba w różnych warunkach meteorologicznych i w różnych lokalizacjach (ze zwróceniem uwagi na wpływ sztucznych źródeł światła na jasność nieba). Wyniki wykonanych pomiarów posłużą do weryfikacji fizycznego modelu modelu nocnego nieba. Model ten ma za celu zidentyfikowanie, jakim sposobem źródła światła (VO, bądź całe miasta) mogą mieć wpływ na jasność nieba w różnych odległościach od źródła światła a w różnych sytuacjach meteorologicznych. (Pomiary zanieczyszczenia świetlnego w warunkach Republiki Czeskiej).

**Keywords:** obtrusive light, illuminance, luminance, measurement.

**Słowa kluczowe:** zanieczyszczenie świetlne, natężenie oświetlenia, światłość (natężenie źródła światła), pomiary.

### Introduction

Light pollution has not been quantified so far from the point of view of separated groups of light sources. We mean for example the public lighting, windows, neon signs, billboards and other light commercials, architectonic lighting, shopping centers and outdoor sport areas lighting. This measurement was focused on the judging one of the light pollution sources – the public lighting, which is considered to be most dominated nowadays.

The real state quantification could have an important influence on looking for the ways of the obtrusive light limiting, solving of citizens', biologists', ecologists', astronomers', eventually other groups' complaints.

The measurements were done to find out night sky glares dates in different localities which were produced by artificial light sources. The results are going to be used for physical night sky model verification. This model should help to set-up different light sources influence (we mean not only the public lighting, but all cities, towns and villages) to the night sky glares, unwanted landscape illuminance and other disturbing effects. We are interested in light source acts locally and in further destinations, both under clear sky and under many different meteorologist conditions too.

In the mid September 2009 was done a large measurement of the night sky parameters. There was switched off the public lighting in all Liberec district. The aim of the measurement was to judge the changes of radiating during the night time which was caused by public lighting and as well as by other light sources. Liberec district was not chosen accidentally. In this area are many different environmental zones (from the industrial and shopping centers to the protected landscape area). Topography of this area is very kindly too, because it is possible to judge light radiating of the whole district from three positions. Last but not least is important the cooperation with public lighting providers. We also used the Public Lighting Study in this district published in 2008.

The measuring stations in Liberec district were chosen so that whole district would be visible and bigger cities would be observable from more measuring stations to compare measurement results. In the picture we can see Liberec district map. There are 4 highlighted comas roses with measuring stations. The number of district citizens is 433 948 and its area is 3.163 km<sup>2</sup>.



Fig. 1 – maps of Liberec district – area where were PL switched off

### Public lighting system description in the district

- Regulation of luminous flux: partly (only 10 % of all public lighting systems)
- Power supply voltage: 230V
- Power supply voltage during regulation: 200V
- Average power consumption of 1 Public lighting (PL) luminaire: 130 W
- General power consumption of PL: 9.217.215 kW

- Number of citizens per 1 PL luminaire: 6,14
- Number of PL luminaires per 1 km<sup>2</sup>: 22,3
- PL systems which are operating whole night (4100 hours/year): especially towns and cities
- PL systems which are operating only part of the night (2870 hours/year): especially villages

**Measuring plan**

We prepared measuring plan, because we wanted to find out maximum information about lighting during night. Our biggest problem was with switching off the public lighting because we could switch off PL in the whole district only for short time.

- 21h – 21h 45min – first measurement, PL and other light sources working 100%
- 22h 30min – measurement effected by windows
- 23h 00min – 00h 00min – measurement with regulated PL (certain urban areas only)
- 00h 00min – 00h 45min – measurement of regulated PL (urban areas where PL is operating only parts of the night are switched off)
- 01h 05min – PL switched off
- 02h 15min – PL switched on again

**Atmospheric (weather) conditions during the measurement**

As the preparing of the measurement was longer than half a year and we cooperated with many people an organizations (all district municipality, police, PL controller etc.) we could not change the date of measurement and we did not wait for the ideal weather. Our conditions were following – cloudy weather and changeable fog.

**Measurement description – Liberec**

Very interesting results were taken from the measuring station in the centre of city Liberec. On this place there were used both the lighting equipment which is correlated by V luminance meters and cameras, illuminance meters) and the astronomic equipment (sky quality meters). Due to cloudy sky there was possible to evaluate luminances produced by reflected matter from atmosphere directly above light source (city) very well. If we evaluate certain illuminances from the graph caused by reflected light from the sky during the night we will make following results:

during the night we will make following results:

- even if there was a cloudy sky, the reflected part of luminous flux is significantly lower (in this certain situation is maximum of illuminance 0,1 lx) than it is allowed by European norms (e.g. EN 12464 - 2 Lighting of work places — Part 2: Outdoor work places). Apart from really dark areas, such as national parks or protected sites where is supposed zero illuminance on the objects, there is in every other environmental zone permitted illuminance higher than 1 lx.
- due to changeable sky conditions the illuminances was increased even if the light sources (e.g. windows, billboards, industry, etc.) were gradually being switched off.
- in our opinion the most important conclusion from this graph is the difference between last 4 graph columns. There are visible the sudden differences among switched on and switched off PL not only in the city, but in the whole district. We could agree that the sudden decrease (increase) of the illuminance is only 50% of original value measured before switching off. We expected more significant differences caused by these PL states.
- in the point of view of the whole night, we can make a conclusion that the illuminances decreasing caused by switching off the PL is approximately only one third of the maximum value measured at the beginning of the night.

Results which are demonstrated by illuminances can be proved by luminance meters and luminance cameras and Sky quality meters too.

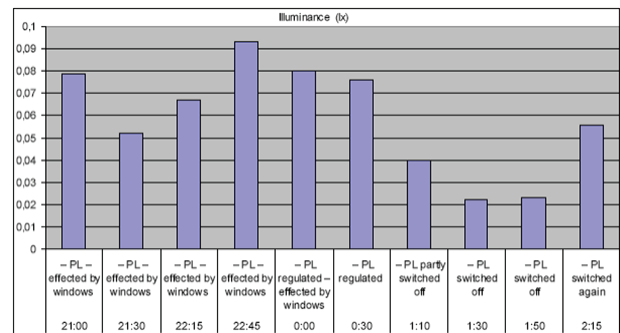


Fig. 2: Graph with measured illuminances in the centre of Liberec (city of the district)

**Measurement description – Bezděz castle**

The station Bezděz was chosen because of several reasons. In its surrounding there are minimums of lighting sources (villages and towns) and its position is near the border of the district. We expected to compare approximately similar light sources (towns) with switched off PL and without switched off PL (other not switched off districts).

- first interesting conclusion from this station is about comparing zenith luminances in this minimally involved area with zenith luminances measured in the centre of city Liberec. In the Bezděz area during the atmosphere conditions which were described above were zenith luminances during night before switching off the PL in range 0,003 cd/m<sup>2</sup> – 0,005 cd/m<sup>2</sup>, while in the centre of the city Liberec it was one level higher, i.e. 0,015 cd/m<sup>2</sup> – 0,035 cd/m<sup>2</sup>.
- after switching off the PL in Bezděz area the zenith luminances decreased to values about 0,002 cd/m<sup>2</sup> while in city Liberec the values decreased only to values about 0,004 cd/m<sup>2</sup>. These zenith luminance values are similar to values which were measured in the Bezděz area before switching off the PL.

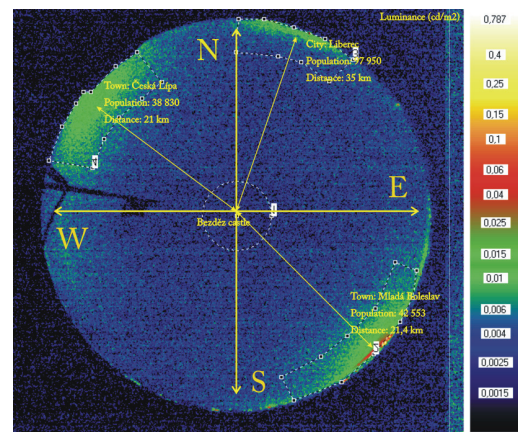


Fig. 3. Luminance map measured from the Bezděz castle

- another very interesting information is from comparing of luminances measured above horizons of some towns where the PL was switched off and switched on. During switching off the PL in the town Česká Lípa was measured an average luminance above the town horizon (up to 20o) approximately 0.002 cd/m<sup>2</sup> while above comparable town Mladá Boleslav was an average luminance above horizon about 0.006 cd/m<sup>2</sup>, which is more than 3 x higher.

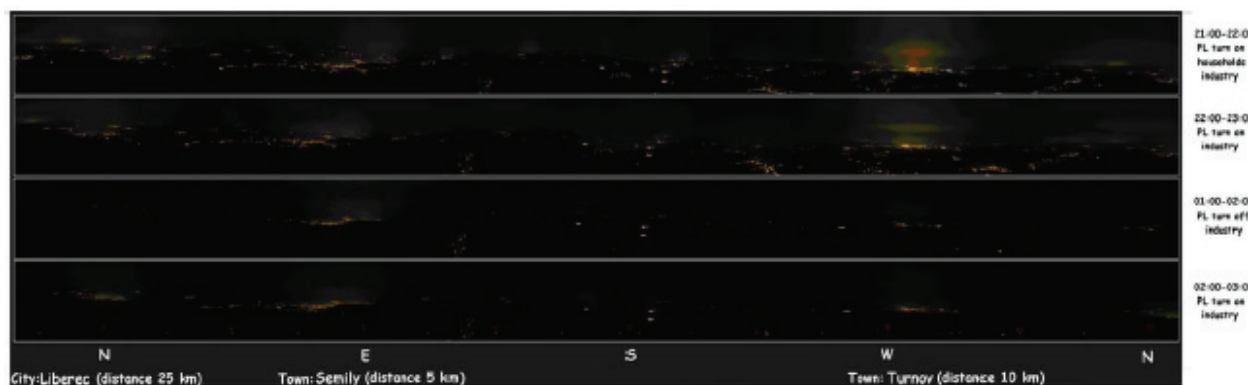


Fig 4. Panoramic photos around Kozákov tower

### Measurement description – Kozákov tower

Measuring station Kozákov has similar parameters as the station Bezděz, but it is situated in the opposite part of the switched off district. On this station were done similar measurements as on the previous ones. But there is an output from the classic digital panoramic photos (not correlated to  $V\lambda$  curve). These photos were taken during different light situations at night (see Fig.4). All photos were taken with the same time of exposure and then they were collected to panoramic view.

- from the photos there is significant luminances decreasing above city Liberec (distance about 25 km). You can notice the fact that the influence of the light from city Liberec (big source) is lower than from the smaller towns which are in shorter distances in the smaller elevation angle.
- another fact which is visible in the photos we can see in town Semily. This town was not switched off PL. During the night it happened that the luminances above this town were decreasing too.
- the most significant influence of switching off the PL was observed in town Turnov (distance about 9 km) where industrial and shopping zones effected the sky with higher luminances to high elevation angles. After switching off the industrial zone still worked, but this certain zone effects the sky luminance increasing only minimally.

### Conclusion

From the measurement results that PL in the big cities in the Czech Republic generate luminous flux to the upper hemisphere which increase sky luminances approximately about one third. With decreasing of the citizens numbers or decreasing of the part of industrial and shopping zones in the populated areas this part increasing. In the small villages is the part growing up and during the night can be up to 100%.

Except expecting reflecting character variability of the night sky together with atmospheric conditions is during starting hours of the night showed strong influence of the windows in the residential sections on the sky luminances increasing. This variability we will study.

Results from this measurement will be used for verification of night sky model behavior. We prepare this model together with our colleagues from Slovak Republic.

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