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Intensity of light pollution and its impact on phenological phases of trees

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Abstract

The work evaluates the intensity of light pollution in two towns of Central Slovakia from September 2013 to April 2014. Under different weather conditions we performed 20 measurements at 7 sites with the instrument of Lux Meter Velleman DVM 1300 during night hours. We found the relationship between the actual weather conditions and measured values. In comparison with STN EN 12464-2, the valid norm of Slovakia, the threshold of 5 lux was exceeded at 5 observed sites by 1.3-10.4 lux. Some trees react to strong light sources. Intensive night lighting caused the visible delay of autumn phenological phase of leaf colouring on some crown parts of several trees.

Key words: Light pollution, light intensity, phenology, Central Slovakia

Introduction

Environment and its health condition affects the whole set of physiological and psychological reactions of living organisms. Everyday life of organisms on the Earth is influenced by pollution of basic environmental components – soil, water sources, and air. Currently, a new phenomenon has occurred – pollution by undesirable and excessive lighting (HABEL et al., 2013). Increased attention has been paid to this issue since the 70s of the 20th century as a reaction to the increasing urbanisation. New questions concerning light radiation, which are being dealt by a great number of professionals from physiology, biology, psychology, architecture, construction engineering, technology and environment hygiene, are emerging (SUCHAN, 2003).

The term „pollution“ is generally understood as a contamination of environment, which means the release of environmental contaminants into environment as well as their presence in the environment. In case of „light pollution“, light coming from the artificial public lighting is the contaminant. The International Dark-Sky Association (IDA) defines light pollution as: “any undesirable impact of artificial lighting causing excessive sky brightness, radiance, infiltration of excessive light into houses, reduced visibility on roads and wasteful energy spending.” (www.vesmir.sk). It can be best observed in towns and wide-spread agglomerations, where the light scatter from public lighting occurs. Light directed towards the sky is reflected from the atmosphere particles (dust, water vapour) and is spread far behind the place of its origin. This is shown by visibly lighter sky also at greater distances from the sources due to which natural darkness that is necessary for the conservation of night ecosystems is lost. Natural darkness is needed for living organisms active during a day and during a night, and also for humans to rest and to ensure the correct course of their circadian rhythms. The issue of light pollution is very broad, affects many areas of life, and has a negative impact on health, animals, plants, transport accidents, economy, and astronomy (RAPAVÝ, 2009).

Some trees also react to strong light sources. If they are situated near the lamps, they do not recognise that winter is approaching. Leaves do not colour, but they freeze fully green. Artificial lighting gives plants a signal that it is a constant day and summer. This causes their continual extinction due to the destruction of their annual physiological cycle. The majority of plants react to this factor by delayed leaf falling and premature mortality (http://www.astronomie.cz/). A man with his demands on intensive light during night destructs environment and indirectly contributes to the increase of greenhouse gases in the atmosphere, and hence, also to the global warming.

Material and methods

The measurements of light pollution intensity were performed from September 2013 to April 2014 in two towns situated in Central Slovakia at different elevations, geographic positions, and climatic conditions. Zvolen as the first town is located in the south-western part of the Zvolenská valley at an elevation of 300 m. It belongs to a warm climatic region, a slightly moist sub-region, to the type of valley climate with great temperature inversion and annual average precipitation total of 703 mm. In Zvolen we selected three sites. Banská Štiavnica is situated at an elevation of 600 m in the Štiavnické Mts. on the border between two climatic types. The region belongs to a slightly warm and a cool climatic region, a slightly warm, very moist and a slightly cool sub-region with the annual precipitation total of 826 mm (LAPIN et al., 2002). Both thermophilic and Carpathian mountainous flora can be found here. In the second town, we performed measurements at 4 sites under approximately same conditions.

The measurements were taken in both towns for a period of six months one night per month between 9pm and 10:30pm using Lux Meter Velleman DVM 1300 instrument. The measurements were performed under different weather conditions – clear and cloudy sky.

We used the methodology described in the work by LÁZNA (2009). The individual sites were divided into a square grid of 100 x 100 m in GIS environment. At each site, we performed 20 partial measurements, from which we calculated the arithmetical mean representing the final value of sky brightness in lux units (lx).

We followed these three principles:

• no obstacles that can cast shadows (buildings, trees) shall be between the instrument and sky

• the measurements shall not be performed on places with direct shadows of the light sources

• the worker performing measurements shall not stand on the place, on which the light flux falls from the source (e.g. under the lamp) (LÁZNA, 2009).

To compare the intensity of pollution in both towns we followed the norm STN EN 12464-2 valid for Slovakia. According to the norm, the highest allowed values of disturbing light in the town centres and residential suburbs fluctuate between 2-5 lux.

Results

In both towns, we performed the measurements under different weather conditions to examine if the change in cloudiness and hence the change in temperature and air humidity affect the measurement values. The measured values are given in Table 1.

Tab. 1. Light intensity (lx) on the sites in Zvolen (ZV) and Banská Štiavnica (BŠ) under different weather conditions

Weather/site	clear sky	clear sky	cloud sky	cloud sky
ZV 1	1.1	1.2	1.5	1.3
ZV 2	3.1	3.3	4.1	4.6
ZV 3	6.0	6.1	6.3	6.6
BŠ 1	13.8	13.9	17.4	16.9
BŠ 2	5.9	6.3	7.2	8.4
BŠ 3	7.3	6.4	11.1	11.9
BŠ 4	10.3	10.7	16.1	16.9

The results confirmed the relationship between the actual weather conditions and the measured values of light intensity. Higher average light intensity was observed in the case of higher air humidity and cloudiness; under clear sky conditions the values were lower. This is caused by higher reflectance of light from rain drops.

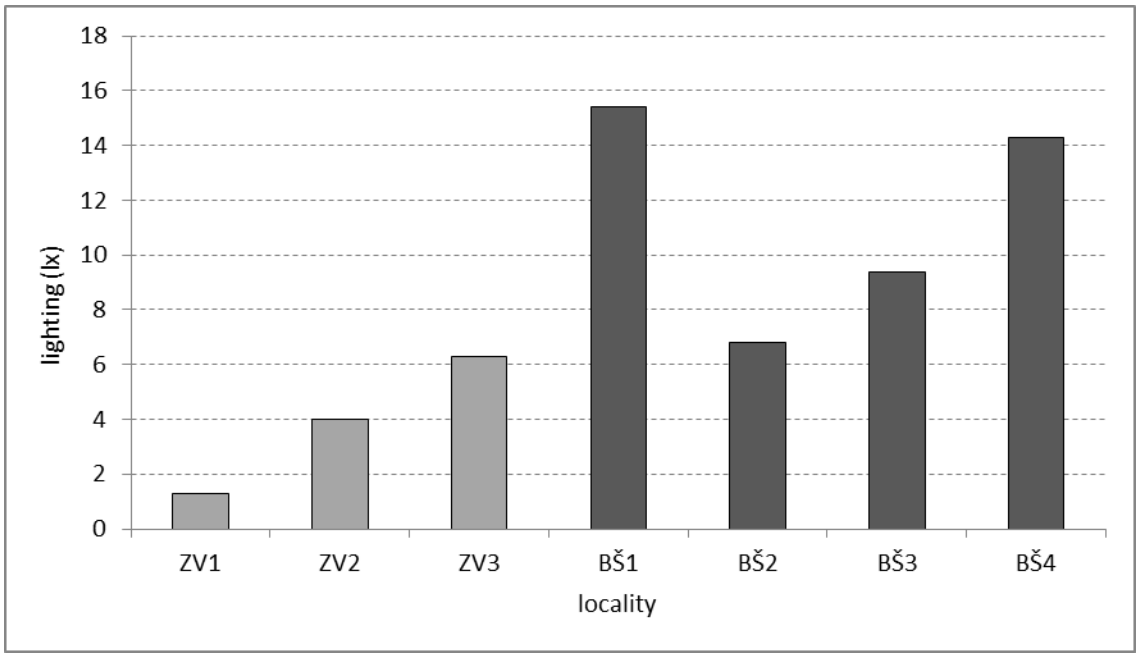

Fig. 1. Final average values of light intensity at individual sites during the measured period

From Fig. 1 we can see that the highest measured values of light intensity were in the central part of Zvolen (ZV 3) and at two sites in Banská Štiavnica (BŠ 1, BŠ 4), probably because of inappropriate type of lighting. The obtained values were compared with the values given in STN EN 12464-2 norm for Slovakia. In the centres of small towns and residential suburbs, the highest allowed value of disturbing light after 10pm is 2 lux. In the areas with high luminosity, such as town centres and shopping areas, 5 lux is allowed. For our sites we selected 5 lux to be the threshold value. We found that at one site in Zvolen, the average value during the whole observed period exceeded this threshold by 1.3 lux. Hence, inhabitants as well as fauna and flora are exposed to the increased concentration of undesirable artificial lighting. At two other sites in Zvolen, the values did not exceed the norm threshold. In Banská Štiavnica, light intensity significantly exceeded the threshold values of the norm at all sites by 1.8-10.4 lux. The lighting in this town is considered inappropriate. It would be desirable to change it with the lamps with flat and tight diffusers. The current state of light pollution affected physiological processes of trees in both towns. The visible impact of intensive night lighting caused the delay of the autumn phenological

phase of leaf colouring in some crown parts of several trees of staghorn sumac (*Rhus typhina* L.) (Fig. 2).

Fig. 2 Impact of artificial public lighting on trees in the town of Zvolen. (Tuhárska, 2013)

The solutions for eliminating light pollution are not complicated and costly. In many cases it is sufficient to change the direction of light rays, to decrease the luminance by substituting fluorescent lamps with sodium arc discharge lamps having orange spectrum, or to restrict lighting by time switches that react to movements during the night hours.

Conclusion

The measurements of light intensity pollution were performed at seven sites of Central Slovakia from September 2013 to April 2014. The sites were situated in two towns (Zvolen, Banská Štiavnica) located at different elevations,

geographical positions and climatic conditions. The measurements were performed during night hours with Lux Meter Velleman DVM 1300 instrument following the method described by LÁZNA (2009). Weather conditions significantly affected light intensity. Under cloudy conditions the average light intensity was higher than under clear sky conditions. Light intensity in Zvolen was 1.1-6.1 lux and 1.3-6.6 lux, under clear and cloudy sky conditions, respectively. In Banská Štiavnica, higher values were measured most probably due to inappropriate type of lighting, which under clear sky conditions reached the values between 5.9 and 13.9 lux, while under cloudy sky the values were from 7.2 to 17.4 lux. According to the valid norm of STN EN 12464-2, the allowed threshold after 10 p.m. in the centres of small towns and residential suburbs is 5 lux. This norm was exceeded at one site in Zvolen by 1.3 lux, and by 1.8-10.4 lux at all sites in Banská Štiavnica. The current state of light pollution also influenced physiological processes of trees in both towns. Intensive night lighting caused the visible delay of autumn phenological phase of leaf colouring on certain crown parts of several individuals of staghorn sumac (*Rhus typhina* L.). The leaves did not change their colour, but they froze green. Artificial lighting disturbs the annual biorhythm of trees and may cause their earlier mortality.

A man with his demands on intensive night lighting disturbs environment. Our days do not finish by sunset. We got used to the life in the light of towns. Let us think if it is not often at the expense of some other parts of our environment that are inevitable for the life of our civilisation.

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Summary

Na strednom Slovensku prebiehali od septembra 2013 do apríla 2014 merania intenzity svetelného znečistenia. Lokality boli umiestnené v dvoch mestách (Zvolen, Banská Štiavnica) s rozdielnou nadmorskou výškou, geografickou polohou a klimatickými pomermi. Za rôzneho stavu počasia sa uskutočnilo 20 meraní na 7 lokalitách. Merania prebiehali v nočných hodinách pomocou prístroja Lux Meter Velleman DVM 1300 podľa metodiky, ktorú popísal vo svojej práci LÁZNA (2009). Počasie výrazne ovplyvnilo intenzitu osvetlenia. Pri zamračenej oblohe dosiahla priemerná intenzita osvetlenia vyššie hodnoty, pri bezoblačnej poveternostnej situácii boli hodnoty nižšie. Vyššiu intenzitu spôsobil vyšší odraz svetla od kvapiek zrážkovej vody.

Vo Zvolene dosiahla intenzita osvetlenia pri jasnom počasí 1,1-6,1 luxov, pri zamračenom počasí 1,3-6,6 luxov. V Banskej Štiavnici pravdepodobne vplyvom nevhodného typu osvetlenia boli namerané vyššie hodnoty, ktoré sa pri jasnej oblohe pohybovali v intervale 5,9-13,9 luxov, pri zamračenej oblohe od 7,2 do 17,4 luxov. Podľa platnej normy STN EN 12464-2 pre územie Slovenska je v centrách malých miest a obytných prímestských oblastiach povolená najvyššia prípustná hodnota rušivého svetla po 22:00 hod. do 5 luxov. Táto norma bola prekročená na jednej lokalite vo Zvolene o 1,3 luxov, v Banskej Štiavnici na všetkých lokalitách o 1,8-10,4 luxov. Súčasný stav svetelného znečistenia v obidvoch mestách sa prejavil aj na fyziologických prejavoch drevín. Viditeľný vplyv intenzívneho nočného osvetlenia spôsobil oneskorenie jesennej fenologickej fázy žltnutia listov na časti koruny viacerých jedincov sumachu pálkového (*Rhus typhina* L.). Listy sa nesfarbia, ale zelené zmrznú a opadnú.

Umelé osvetlenie ruší fyziologické procesy drevín a môže spôsobiť ich predčasný úhyn. Negatívne dôsledky svetelného znečistenia výrazne ovplyvňujú aj faunu. Živočíchy zvyšujú svoju fyzickú aktivitu v noci, čím menia svoj biorytmus, orientáciu v krajine, koncentráciu za potravou a reprodukciu.
Znečisťovanie nežiadúcim a nadmerným osvetlením ničí životné prostredie, nepriamo prispieva k zvyšovaniu podielu skleníkových plynov v atmosfére a tým aj ku globálnemu otepľovaniu.

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