

# Light Pollution

Working paper

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## Introduction

Light pollution is one of the fastest growing and most pervasive of environmental pollution (Chepesiuk, 2009). In the last couple of years, a lot of research has been done about the effects of light pollution. The interest in light pollution has been growing in many fields of science, extending from the traditional field of astronomy to atmospheric physics, environmental sciences, natural sciences and human sciences. Better insight in light pollution is likely to contribute to design and operation of Facility Management (FM) based on evidence. According to Cinzano, Falchi, & Elvidge (2001), the Netherlands is one of the countries with the highest amount of light pollution, just as the United States. A sample of students in the Netherlands and the United States has been taken to explore differences and similarities between the two countries.

## Light pollution

Light pollution is a worldwide acknowledged problem. Not only cities but whole countries are lid at night, mostly because of artificial lighting. For eighty percent of the U.S. population and one fourth of the World population, artificial light levels of the night environment are even greater than sky brightness on a night of full moon in a place on earth without light pollution (Cinzano, Falchi, & Elvidge, 1999). Light pollution has negative affects on life on earth, including astronomy, ecology, and human health (Chepesiuk, 2009; Gaston, 2013; Navara & Nelson, 2007; Rich & Longcore, 2005; Riegel, 1973). For millennia, mankind has been fascinated by the stars (Romano, 2002) and the night sky contributes to our perception of the natural world (Dick, 2011). Visibility of the stars with the human eye is an easily comprehensible measure of light pollution. At 3 – 9 times natural brightness level, The Milky Way is no longer visible. At 9 – 27 times, fewer than hundred stars, at 27 – 81 times, the North Star, and at 81 – 243 times, the Big Dipper is no longer visible (Cinzano, Falchi, & Elvidge, 2006). Two thirds of the U.S. population and more than one-half of the European population have already lost the ability to see the Milky Way with the naked eye (Chepesiuk, 2009).

The first World Atlas of the artificial night sky brightness (Cinzano et al., 2001) maps light pollution and sky brightness in the World. The map shows the fraction of the population who are living under the threshold to consider the night sky polluted. The threshold is reached when the artificial sky brightness is greater than 10 per cent of the natural night sky brightness (according to

Smith, 1979 in Cinzano et al., 2001). Table 1 shows sky brightness in the United States, the Netherlands and the European Union. Nepal is added purely for reference: it is one of the countries with little light pollution. The table shows that about two thirds of the Dutch and U.S. inhabitants are not able to see the Milky Way, around eighty percent sleeps under a night sky compared to a perennial full moon and more than 99 per cent of night skies in the Netherlands and United States are polluted.

Gross Domestic Product (GDP) and population density are explanatory variables of light pollution (Gallaway, Olsen, & Mitchell, 2010). Light pollution in the United States and the Netherlands is evident. Nonetheless, differences in light pollution between both countries are observed. In the Netherlands forty percent of the population is able to see the Milky Way, in the United States thirty percent. In the Netherlands, light pollution is more widespread over the surface of the country, in the United States around forty percent of the surface is not light polluted. Moreover, a survey (n = 2.053) of Lyytimäki and Rinne (2013) showed respondents in more densely populated areas considered light pollution less a problem. The question arises as to which differences can be observed between residents of densely populated areas in both countries.

**Table 1**

**Sky brightness as percentage of population or surface area**

(source: Cinzano, Falchi, & Elvidge, 2001)

(*)	(1)	(2)	(3)	(4)	(5)	(6)
	Light pollution > 10% $b_n$	Natural sky brightness > $b_n$	Full Moon	Visibility of the Milky Way > 6 $b_n$	Natural sky brightness	Light pollution
		population			surface	
Nepal	26	9	2	0	0,3	3,1
European Union	99	90	68	51	36,7	85,3
Netherlands	100	100	85	60	96,7	100
USA	99	93	81	71	22,5	61,8

thresholds in  $\mu\text{cd m}^2$      $\pm 25$                       252                      890                       $\pm 1500$                       252                       $\pm 1500$

(\*)  $b_n$  = natural sky brightness

**Causes of light pollution**

Light pollution is the effect of inefficient and unnecessary artificial outdoor lighting (Chepesiuk, 2009). The biggest light pollution source comes from street lighting. Other sources are, e.g., commercial lights, light from urban areas, yard lights, road lights, and decorative outdoor lights. The complete list of light pollution sources is much larger (Lyytimäki, Tapio, & Assmuth, 2012; Lyytimäki & Rinne, 2013). Chepesiuk (2009) identifies sky glow, trespass, glare and over-illumination. Sky glow is the halo over urban areas, light trespass is unwanted artificial light spilled over adjacent properties, glare is unused light that shines horizontally, and over-illumination is nonfunctional use of

light. Gaston, Davies, Bennie and Hopkins (2012) suggest five management options to reduce light pollution: reduction of duration, trespass, intensity, and spectrum of lighting, and preservation of unlit areas. Moreover, FM can contribute to reduction of light pollution by usage and design of illumination of their properties.

Street lights illuminate the sky, where no light is needed (Borg, 1996). Solution for unnecessary roadway lighting is, i.a. in the design of electrical lighting fixtures. Distribution of light can be better directed towards objects by physical design alterations. Adaptation of vertical and lateral light distribution to illuminated objects and reduction of glare by use of cut-off fixtures (Chepesiuk, 2009; Shaflik, 1997) will result in reduction of light emission, lower energy use, and lower exploitation costs (Borg, 1996; Shaflik, 1997; Struijs, den Hollander, Alferdinck, de Kruijter, & van Hoek, 2009).

### **Effects of light pollution**

The effects of light pollution have their influence on both plants and animals, including human beings (Longcore & Rich, 2004; Navara & Nelson, 2007). A review of empirical studies by Navara and Nelson (2007) on effects of light pollution shows convincing evidence of physiological and medical implications, i.e. cancer, immunity system, energy metabolism, and eating behavior. These findings are consistent with the findings of Hölker et al. (2010). They argue that light pollution has effects on flora and fauna, and socioeconomic and physiological effects on humans. They contend that more empirical research about the influence of light pollution on those subjects is necessary to make definite conclusions. Nonetheless, a compelling amount of epidemiologic evidence points to a consistent association between exposure to indoor artificial nighttime light and health problems such as breast cancer. This doesn't prove that artificial light causes the problem; although it is proven that exposure to light during the night can disrupt the circadian clock. This affects physiological processes in almost all organisms.

### **Perception of light pollution**

It is not entirely clear whether night skies are more light polluted in the Netherlands or in the United States. The data of Cinzano et al. (2001), as mentioned before and listed in table 1, do not provide information to explain the differences. More detailed information about the perception of light pollution may provide an explanation for the differences between the two countries. Light pollution is more common in urbanized areas (Cinzano et al., 2001; Gallaway et al., 2010). A sample of students is likely to be definitive, because students mostly live in cities. Three-quarters of the students in the north of the Netherlands, almost 54.000 in total, live in the three largest northern cities, whereas only twenty percent of the total population of the north of the Netherlands lives in

the three northern cities (CBS, 2013). It is therefore expected that students perceive negative aspects concerning light pollution in their residence. No U.S. information is currently available due to lapse in government funding (United States Census Bureau, 2013).

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