Light as a Pollutant of the Night Environment: reality, impacts, remedies

Description and Substantiation of the Project
submitted to the Czech Science Foundation

Jan Hollan

Apr 9, 2004, amended Aug 25

1 Current knowledge and the results of our grant from 2003

Pollution of the night environment by artificially added light as an "airborne" pollutant is increasingly considered as a serious issue. Articles and programmes in both the leading world media and local media all over the world suggest this, as does the existence of and preparation of relevant local and regional laws.

However, there had been little knowledge about the extent and impact of this pollution. Our short research project from autumn 2003 (VaV/740/3/03) funded by the Czech Ministry of Environment contributed a lot to learning this issue. For Czech readers, its final report summarised the knowledge existing prior to our research (quite often for the first time in Czech language). From the viewpoint of science, it opened new fields of research, formulated novel methods of measurement of light, and collected unique data on the state of night environment and of impacts of its being polluted by light.

People reading Czech can find the whole set of results at `recetox.muni.cz/noc` – there is the report with attachments from many authors, as well as the directories with images and data referred to in these texts. It's a huge amount of information from many disciplines, which waits for translation into English to become accessible to the world public.

2 Why further research is needed

In principle, it might not be necessary to study the problem any more, as far as the restoration of the night environment is concerned (or just conservation, in those rare regions with an unpolluted night). The ways to protect the night environment are well known to the handful of principal world experts, there is a consensus as to which measures are "necessary and sufficient" to reverse the growth of pollution, and cause its steady decline. Theoretical papers by Pierantonio Cinzano show that well enough. Laws valid in two Italian regions, Lombardy and Marche are an excellent example: with just minor additions, they will be able to realise this reversal. Even current development is very positive already. The minor additions concern lighting of advertisements etc. and are included in the proposal for a bill to be included into the existing Czech Clean Air Act (see `www.astro.cz/darksky` in English or `www.veronica.cz/noc` in Czech).

However, politicians and clerks in the national, regional and local executives are no experts on night environment and they don't readily understand theory of light propagation in the atmosphere, theory of twilight and nighttime vision, and not even the quantities and units used in photometry. They can be under an influence of the business connected with artificial lighting – various representatives of this business are often considered as experts (if not the *only* experts) on lighting, which they of course consider to be entirely beneficial wherever added to the previously unlit environment. There is a lot of examples, when the initial political goodwill to do something against light pollution has been invalidated by the influence of lighting industry or its R&D institutes. Either no laws have been introduced in such cases, or ones which not even slow down the rise of pollution, but make a wonderful excuse for it as well: our brave new lighting is made according to the anti-pollution law, so it does not pollute at all, nobody can object to it! "Junk science" financed by lighting industries in the UK led the British Home Office to the erroneous recommendation that adding more light can reduce crime (see a short article by Marchant, 2003). Not only is that nonsense with no foundation in true research results (it's based just on a common superstition), but it seems to be really counterproductive (the only correlation between lighting and crime found up to now is a positive one, i.e. stronger lighting leads to rise in crime, Clark 2003). The only ones who profit are the lighting businesses...

Restoration of the night environment to a healthy, pleasant and safe state should become a process which starts not just very exceptionally in isolated places, but everywhere on a national and then continental level. To make it true, much more knowledge has to be accumulated. So much that the problems, consequences and remedies will be evident to the environmentalists of all kinds, to the general public, politicians and executives. Exactly as with another kinds of pollution, where the process of cleanup started long ago and had been successful (many kinds of the chemical pollution of the atmosphere and of freshwater systems).

3 Scotobiology

The science of night environment is just emerging. One of the milestones had been the Ecology of the Night conference in September 2003 in Muskoka, Ontario, Canada. The new discipline, *scotobiology*, had been invented (or named) during its preparation (Bidwell 2002), see `ecologyofthenight.org`. Prior to that, two important meetings marked the way: one on influences of light-at-night on endocrinology and cancers (see `www.uni-koeln.de/symposium2002`), the other on the wildlife (`urbanwildlands.org`). Before that, most of the concern had been devoted to the artificial skyglow only, at many meetings attended predominantly by astronomers.

4 Our goals

4.1 Luminance of the sky as an indicator

Curiously, even the original astronomical concern about the increased skyglow has seldom been treated in a scientific way. There is a marked lack of quantitative data on skyglow, i.e., the artificial increase of the luminance of the night sky. The only comprehensive set exists for Italy, again thanks to the efforts of Cinzano et al. Sky luminance in the rest of the world, with the exception of just a couple of observatories, is computed only on the basis of satellite measurements of terrestrial emissions (the famous World Atlas of Artificial Sky Luminance is

again largely a product from the only scientific institute dealing with light pollution, established and led by Pierantonio Cinzano, ISTIL).

In our short introductory research from autumn 2003, we got some sky luminance data for one new site at least, namely for the Brno observatory. Much more data can be processed for this site, from the huge amount of photometric observations carried out there in past decades and made further on. The same task can and should be done for another Czech observatories. The evaluation process should become so well automated, that most European and world observatories, both professional and amateur ones, could be included later. Getting reliable data on sky luminances (for various weathers, landscapes and times) is achievable and much needed.

One very practical question can be answered this way. Lighting professionals don't read papers on the science of light pollution[1]. They still claim that most of the light pollution comes inevitably from the lit ground, and that the polluting influence of direct light from the luminaires is unimportant, as far as skyglow is concerned. Fortunately, there is a simple way of demonstrating the role of direct light. If there is a snowstorm and the sky clears short after it, the ground is white, dispersing six times more light then a bare winter ground. If the skyglow would rise six times as well, then the role of direct light would be proven to be zero. If it rises just three times, it would mean that the influence of direct light for snow-less conditions is dominant; if it rises less then twice, then the influence of snow-less lit terrain on the sky luminance would be proven as really small: excluding direct upward light, the sky could be up to five times darker without any reduction of the illumination of the ground. Preliminary results show that even inside a city (Brno) this latter case may hold. To get persuasive answers, processing a rich series of old measurements should help, including those of atmospheric transparency. The corresponding data on the snow cover can be obtained from the weather service.

In our previous grant, we have developed methods of measuring the sky luminance by standard astronomical means, but also of measuring it by ordinary modern digital cameras. The latter way means better portability and possibility to investigate various sites easily and cheaply. By this method we've measured e.g. the luminance of the major aurora of Nov 20, 2003: they have been from less then one millinit to maximum of ten millinits. Regarding that the polluted Brno sky has typically some five millinits, it means that fainter parts of aurora are hardly visible (they are discernible just if they are deep red, a colour fortunately typical for extremely strong aurorae) and even the strongest aurora events mean just a rather inconspicuous change of the standard city sky...

4.2 Glare as a main hindrance to seeing the Universe

During the Ecology of the Night conference, I proposed creation of glare-free and broad-horizon sites in cities, from where the twilight landscape and night sky could be admired. Our research from autumn 2003 proved that people are aware that the main reason why they don't see stars is not skyglow, but glare from luminaires. This is something we want to investigate further: how much it helps when glare is prevented. The target group will be not just people with normal sight, but also people with sight disabilities. Some of them may be able to see stars, when observing from a place where the stars will be the only prominent objects. Maybe, for the first time in their lives.

[1] I'd be happy to learn if there is an exception, please inform me...

4.3 Glare as an aesthetic and safety problem

There are many cases where the visibility of the night landscape is seriously damaged by directly visible light sources and other glaring areas (space angles, to be accurate). We have collected many images of such scenes, which deserve to be processed and evaluated; many more should be taken at night at various sites, to illustrate the seriousness of the problem. Our method enables to evaluate glare quantitatively, with digital images. Parallel field experiments with people with sight disabilities should be made, to study how badly the common glaring lighting systems serve their purpose, and how large is the advantage of using the best available technology with as little glare as possible.

Attitudes of the public to changing the glaring lighting at selected sites to a quality, low-glare lighting should be studied, together with documenting the change with digital imaging photometry.

4.4 Health issues

Dark is as necessary for us as light. This knowledge is somehow expressed in the very beginning of Genesis. Whereas the probable contribution of lack of darkness to rising incidence of cancers is now being studied, the very simple fact that people sleep worse in the absence of dark is still beyond the scope of science. Our past grant brought one of the first results on this issue. One third of Czech people suffers from insufficient dark for sleep and five per cent report it as a major reason of sleep problems. The levels of pollution of darkness by light which are perceived as already unpleasant or disturbing should be investigated. At the moment we can't say much more that one millilux of illuminance of the face is very probably tolerable.

We have an indication, that light at night causes hypertension. More data on blood pressures should be obtained, together with measuring the actual light levels.

"Light" is perhaps not the best word, as this is something we *see*. For some purposes, as the synchronisation of the circadian rhythm, a *non-imaging* visual apparatus (unknown in the past millennium) is important, whose sensitivity has a narrow peak in the blue region. Let's call it *melanoptic vision*. We've got a hint that this system's sensitivity matches quite well the sensitivity of blue pixels of digital cameras. The *melanoptic luminance* of our night environment is the influence which disturbs the circadian rhythm and leads probably to more cancers. We should develop our radiometry methods to the stage when we will be able to report photopic, scotopic and melanoptic "light" quantities, i.e. introduce melanoptic lumens and luxes.

4.5 Wildlife

It is suspected that due to lighting, populations of night-active insects have been diminished by an order of magnitude in urbanised areas (Eisenbeis 2001 and Povolný 2003). It's not easy to get data on the abundance of populations half a century ago, but it may be possible. A recent British survey collected such data; we hope that day and night animals could be distinguished in them, to identify the damaging role of light at night.

Another unresolved issue which at the is that of light levels in the national parks and another protected areas at night. From Cinzano's work, some results can be obtained for clear-sky conditions. Real measurements were made in US national parks recently (Moore 2003). However, in the case of Czech national parks, there is often more light when the sky is overcast, especially when the landscape is covered with snow.

Observers of night nature, as well as hunters, are well aware of the very different behaviour of animals in moonlit and moonless nights. What is the influence of constant lighting, mimicking full-moon nights for all winter?

Unusual behaviour of birds in urbanised areas is often mentioned by ordinary people: some birds are confused to such an extent that they begin to sing deep in the night, with an erroneous assumption that twilight has begun. What does this misleading light signal do to bird reproduction and numbers?

Sterility of urbanised areas lit by glaring luminaires, as regards insects and the food-chain dependent on them, has been not investigated yet. We have proven that shielding a luminaire helps a lot, in our previous research (Pavel Bína did the study).

4.6 Remedies

We should make an experiment, where we will shield all luminaires within a village, and study the revitalisation of the area as far as wildlife is concerned. Also, we should ask the public how they like diminished pollution of their bedrooms and reduced glare.

5 Our background

Our team is perhaps the only one in the world which is able to do such a multidisciplinary research. The only other night-research team we are aware of is that of the Institute of Science and Technology of Light Pollution from Italy. Our scope seems to be a bit broader, concerned with health and wildlife as well, not so much with astronomy-related issues. The grant for which we apply should enable us to proceed in the research we began in autumn 2003 (as mentioned above, its results are available at `recetox.muni.cz/noc`). It is a pioneering work in the world context, something the Czech Republic can be proud about.

6 Addendum on Obesity and Lack of Darkness

Just recently, Apr 5, I remembered one important issue which should be investigated. I mean the influence of artificial lighting on obesity.

Obesity of more and more people including children is a quickly expanding disaster. I think I have read somewhere (I don't remember where, perhaps it had been of US origin[2]) that a seasonal signal of nights getting longer in late summer and autumn is masked by artificial lighting. As many boreal animals accumulate fat in that period, to survive winter and eventually to have offsprings, we can speculate people do the same. This used to be a vital adaptation until not much more than a century ago. However, winter never comes in our time, so accumulation of fat (or appetite to eat more than needed) proceeds unchecked.

When I mentioned this missing long-night signal (during some break at the Ecology of the Night conference), Steven Lockley suggested a possible different mechanism, namely a year-

[2] I found it on Aug 22-24, thanks to a very interesting new paper – Stephen M. Pauley: Lighting for the human circadian clock: recent research indicates that lighting has become a public health issue. *Medical Hypotheses* Vol. 63, 4, 2004, pp 588-596 – as the last reference there. Searching info on that reference, I revealed I read about the problem years ago already in the 2000 version of Dr. Clark's revealing paper (see `amper.ped.muni.cz/light/crime`), the very paper I studied thoroughly and proudly put on my website! Clark summarizes the book by Wiley and Formby, see the end of this obsolete Addendum by an oblivious author...

round sleep deprivation. We can guess there had been enough time for sleep in winter until expansion of electric lighting, and enough dark to sleep well.

As we are aware of possible causal links between lack of dark and obesity, and of the problem obesity presents for the rich part of our world, we have to include the problem in our research.

This is something which should be mentioned e.g. at the First Joint Meeting of SLTBR and AAMCC. Sparse relevant links on seasonal changes in fat accumulation I found on Internet initially are by Petteri Nieminen, *The (un)natural history of endocrine weight-regulation* and a purely zoological abstract on lemmings by Hunter HL, Nagy TR, *Body composition in a seasonal model of obesity....*

The length of interval of night melatonin secretion had surely been seasonally dependent in humans in a natural boreal environment, as contrasted to early research results for young Czech scientists (working hard all the year round...) – as I learned from a recent lecture of Helena Illnerová here in Brno.

Some relevant papers found in PubMed (I know just the abstracts):

- No seasonal difference in the duration of elevated night melatonin concentration was found in an early work
  Illnerova H, Zvolsky P, Vanecek J: The circadian rhythm in plasma melatonin concentration of the urbanized man: the effect of summer and winter time. *Brain Res.* 1985; 328:186-189.
- Such a difference has been found in
  Vondrasova D, Hajek I, Illnerova H: Exposure to long summer days affects the human melatonin and cortisol rhythms. *Brain Res.* 1997; 759:166-170.
- An earlier research showing seasonal varition is
  Stokkan KA, Reiter RJ: Melatonin rhythms in Arctic urban residents. *J Pineal Res.* 1994 Jan;16(1):33-6.
- Increased obesity risk is mentioned in
  Qin LQ, Li J, Wang Y, Wang J, Xu JY, Kaneko T: The effects of nocturnal life on endocrine circadian patterns in healthy adults. *Life Sci.* 2003 Sep 26;73(19):2467-75.

6.1 Where the above idea came from

This piece of information has been added on Aug 25. I apologize I "discovered" it so late.

There is a detailed book about the problem, formulating the hypothesis much better that "I did" in this Addendum. That's the original source of the idea (my forgotten source summarizing the hypothesis and giving that reference was Clark 2003 – Outdoor Lighting and Crime, Part 2):

Wiley, T. S. and Formby, B. (2000) *Lights Out: Sleep, Sugar and Survival.* New York, NY: Pocket Books (Simon and Schuster).

It's a pity their ideas seem to be so little investigated up to now. Perhaps the book is not peer-rewiewed and so not considered as relevant to scientists?

Clark summarizes the Wiley&Formby hypothesis in these words:
"Year-round summer-length duration of daily light exposure in humans and domestic animals appears to lead to increased appetite, carbohydrate craving and fat storage in preparation for the winter famine that never comes, increasingly leading to excess weight, obesity and consequent obesity-related disorders and diseases."

7 Acknowledgement

Apart from the Addendum, the above text is essentially the same as that contained in the grant application. Just the English of the original text had been poor. The current version is surely easier to read than the first public one from Apr 1.

I'm much indebted to Bob Mizon for correcting my text from "English" into English, and to Steve Pauley (see ev. one of his lectures) for a suggestion that the text *should* be corrected.