

The Medical Implications of Light At Night (LAN)

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Summary

Light at night (LAN), sometimes known as light pollution by astronomers, is a little understood environmental problem that has deteriorated over the past forty or fifty years. It is now increasingly obvious that it is having serious ecological and sociological consequences. What isn't generally known is that it also has health implications of which medical practitioners should now be aware. The causes of the problem are explained and a variety of simple solutions are offered.

Key words

Light At Night (Light pollution).

Photogenic Global Warming.

Light nuisance.

Glare.

Urban heat engine.

Circadian rhythm.

Introduction

Whilst the familiar concept of light pollution is defined as unwanted light that leaks out into the environment at night, light at night may well be having more serious effects. For completeness we need to discuss what it is, its causes, environmental effects, and how awareness of the problem was raised.

Light pollution can take three of the following forms:

1) Skyglow (fig 1). This is caused by light from cities being reflected off aerosols in the atmosphere. It increases the brightness of the sky background and reduces the number of stars that will be visible.

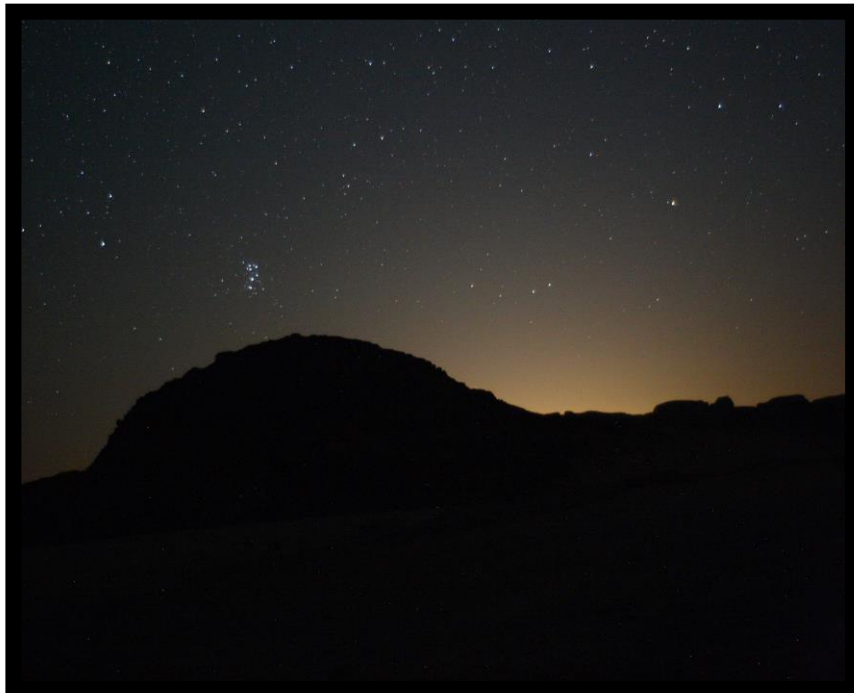


Fig 1: Skyglow from the city of Tabuk, in Saudi Arabia, seen from a distance of about 80km. Image: C. Henshaw.

2) Light trespass (fig 2). The intrusion of unwanted light across property lines into bedrooms, gardens and back yards.



Fig 2. Light trespass. These two houses are floodlit by a neighbour's security light that is permanently switched on during the hours of darkness. The light penetrates the two bedrooms facing the light, much to the annoyance of the occupants, but the neighbour did nothing about it until one of the occupants complained. Image: C. Henshaw.

2) Glare. The direct intrusion of light from unshielded light sources (fig 3), as exemplified by the dazzling effect of oncoming car headlights.



Fig 3: Glare, caused by inappropriate lighting. The unshielded light located on the gable end of this house was installed to enable worshippers attend a local mosque. Complaints had been made that they couldn't find their way to attend the Maghrib, Ayesha and Fajr prayers that occur during the hours of darkness. In fact the situation became worse as anyone approaching the light was dazzled to the point that he could hardly see the ground beneath his feet. The light was never necessary and the problem could easily have been solved simply by asking worshippers to use a torch. Image: C. Henshaw.

Any one of the following sources can cause light pollution:

- a) Street lighting.
- b) Security lighting (both domestic and commercial).
- c) Commercial lighting (empty offices with their lights left on all night).
- d) Decorative lighting (floodlighting, illuminated regeneration follies, skybeams and lasers).
- e) Sports facilities.
- f) Advertising (billboards and flashing signs).

When used judiciously, carefully applied lighting can be beneficial. Many people have to work or travel at night, so obviously they will need some kind of lighting. Unfortunately though, lighting that has not been carefully planned can cause serious environmental damage, and this can have a deleterious effect on human health and quality of life.

The various environmental effects of unwanted light can be outlined as follows:

- 1) Wastage of energy.
- 2) Wastage of money: the energy consumed has to be paid for.
- 3) *Causes global warming and climate change: because of this, light at night becomes an inconvenient truth.*

- 4) Reduces visibility of stars at night.
- 5) Kills insects. This has concomitant effects on higher order consumers and reduces the number of successful pollinations in flowering plants.
- 6) Affects plants.
- 7) *Disturbs circadian rhythms in animals and humans.*
- 8) *Causes accidents.*

Those of particular relevance to health are shown in *italics*.

A casual glance at satellite imagery of the Earth at night¹ will reveal the lights of thousands of cities containing millions of street lights, as well as security, commercial and decorative vanity lighting. All of this lighting, radiating considerable amounts of heat and light into the environment, must be having an effect. They are, in fact, contributing to urban heat engines that are cooking the atmosphere all night, every night, three hundred and sixty-five nights a year. However the contribution of wasted energy pales into insignificance when compared to amount of energy consumed in keeping them going. As much as thirty-eight percent of a city's energy budget goes on lighting², and this may be substantially more in some urban areas. All of this results in *photogenic global warming*, derived from carbon dioxide emissions

produced by the combustion of fuels used in keeping the lights going. The rest comes from vehicle exhaust emissions, heating, air conditioners and industrial production. This has been going on for decades, a creeping, insidious cancer of the environment that nobody noticed until amateur astronomers in urban areas began to complain that it was affecting their observations. By the end of the 1980's the astronomers began to militate against it, thereby bringing it to the attention of the population at large. They began to raise its profile amongst all the other environmental issues that were affecting and still affect the general well-being of the planet. This being the case, it is still largely ignored as a serious environmental problem, just like most other environmental issues.

The Effects of Light At Night on Humans

Photogenic global warming can have serious implications for human health. Climate change is brought about by the carbon dioxide derived from the fuel consumption used in motor vehicles, air conditioning, industrial production, domestic heating and lighting, and keeping cities illuminated. As the climate changes, the climatic zones start to widen further away from the equator, giving the potential for tropical diseases to spread into more

temperate climes. Diseases like malaria, leishmaniasis, dengue fever, and Japanese encephalitis may then spread into areas where either they were eradicated or never existed before.

Exposure to light at inappropriate times can have a number of undesirable effects. It can lead to sleep deprivation, depression, fatigue and impaired thinking. This in turn can lead to accidents. Exposure to dim lighting can lead to depression³, while exposure to fluorescent lighting, especially in schools and offices can lead to work related stress, high blood pressure and, again, depression. It can also affect human fertility⁴. Sperm count in men has been shown to have declined by about 50% in the fifty year period leading up to 1991⁵; exposure to blue light at night is known to affect fertility in mammals⁶, so the increased exposure to light at night over this period may have been a contributing factor. Exposure to light at night can also have unfavourable psychological effects that can affect the chemistry of the blood and urine. This is an example of the effect of psyche on soma. The affected patient may not have sufficient REM sleep, during which the body produces antibodies and *melatonin*.

The body works on natural twenty-four hour cycles, or circadian rhythms, that are dependent on the rising and setting of the Sun.

Circadian rhythms are twenty-four hour cycles of physiological behaviour in living organisms, ranging from bacteria to plants, animals and humans. They control daily rhythms of sleep, hormone production, and essential aspects of cell physiology. As a result of genetic sequencing it is now known that 15% of the genome is regulated by the body clock. The function of every organ in the body is therefore rhythmic. It has been reported⁷ that most cells have a core set of circadian clock-genes for proteins that not only regulate their own expression, but also that of clock-output genes and metabolic pathways throughout the genome. It has been said that a cycle of very bright days and very dark nights is the perfect regulator for the human circadian system, but patterns of light and dark in today's modern world are often inconsistent with this cycle. Nocturnal shift work can disrupt these natural rhythms and adversely affect the body. This creates similar problems to trans-meridian travel that results in jet lag. Similar manifestations are seen in people living in high northerly latitudes when the sun hardly sets during the summer and barely rises in the winter. This can affect the suicide rate. Long term exposure to continuous light disrupts circadian rhythms in mice⁸ but it probably applies to other mammals as well. Furthermore it

caused impaired skeletal muscle function and trabecular bone deterioration. Once the mice were returned to a standard light-dark cycle, the above mentioned problems returned to normal.

In addition to the rods and cones, the eye contains other non-visual receptors, the *intrinsically photoreceptive retinal ganglion cells, or ipRGCs*)⁹, that respond to retinal illumination independently of those that are responsible for vision. They measure information about the lengths of day and night at a subconscious level. These cells become responsive through the expression of a pigment, melanopsin, that has a peak spectral sensitivity (λ_{\max}) of 480nm, towards the blue end of the spectrum. They are the principle conduits to circadian and other systemic responses to light and link up with the Hypothalamic Suprachiasmatic Nucleus (fig 4) through the optic nerve¹⁰ via the retinohypothalamic tract¹¹. In vertebrates circadian rhythms are maintained by the Hypothalamic Suprachiasmatic Nucleus which is connected to the Pineal Gland, (a structure about the size of a pea in humans that is located inside the brain) by the Paraventricular Nucleus (fig 5). The pineal gland secretes a hormone, *melatonin*. More melatonin is secreted during the night, and exposure to light at night, especially light containing a substantial blue component¹²,

suppresses melatonin production. The current change from sodium to blue-rich metal halide or LED street lighting could suppress melatonin production by as much as five times normal levels¹³. This can be alleviated by replacing the blue-rich LEDs with low colour temperature (ideally 2000K and not exceeding 2700K) amber coloured LEDs¹⁴.

Melatonin also serves to reduce cholesterol levels and reduce blood pressure. It is a known antioxidant that helps to maintain the body's immune system by stimulating T-cell production, and is also important in protecting nuclear and mitochondrial DNA. It has been used in the treatment of Seasonal Affective Disorder, and ADHD - Attention Deficit Hyperactivity Disorder - to offset the effects of other drugs used to treat it that are known to cause insomnia. Melatonin is *oncostatic*, indicating that it is important as a Cancer suppressor¹⁵.

A study at Oregon University found that disruption of circadian rhythms in mutant fruit flies, *Drosophila melanogaster*, caused neurodegeneration, impaired motor function and premature death¹⁶. At first it wasn't known whether the circadian disruption was the cause of the neurodegeneration or the result of it. The researchers said earlier studies had found close parallels between

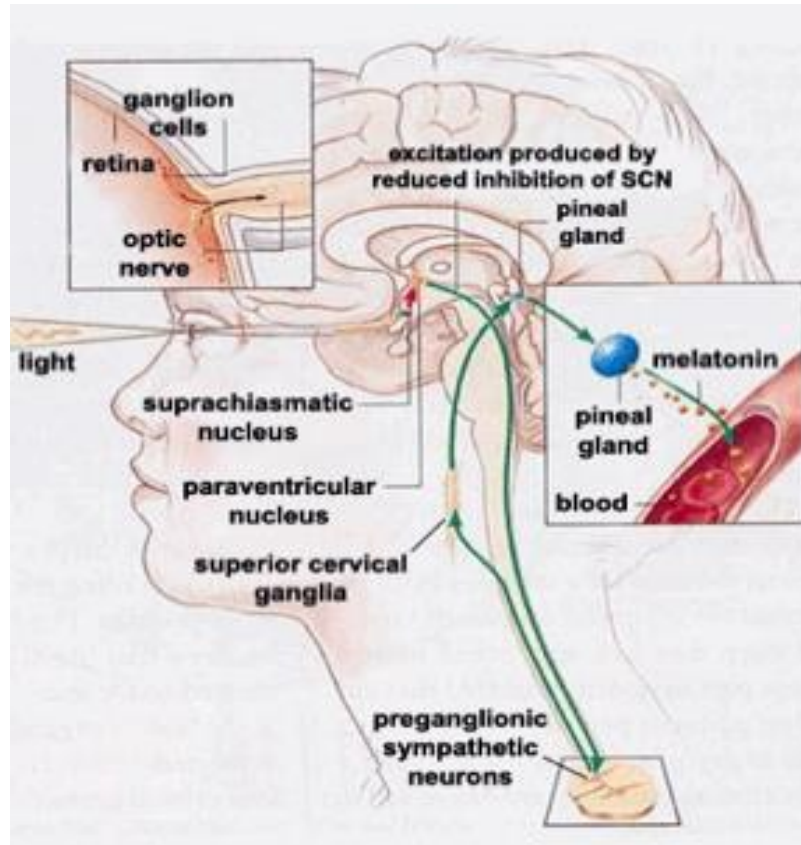


Fig 4: The suprachiasmatic nucleus. Credit: Vince Giuliano, <http://www.anti-agingfirewalls.com/2012/02/27/blue-light-sleep-mental-alertness-and-health/>

fruit flies and humans. Some of the genes regulating circadian rhythms have been preserved in both human and fruit fly lineages since their ancestors diverged millions of years ago, so it is very likely that the genes function in a similar way in humans. In humans strong correlations have been found between disrupted clock mechanisms, aging, and neurodegenerative disorders such as Alzheimer's Disease¹⁷.

It has been found that the incidence of breast cancer in women, and prostate cancer in men, is greater in urban areas that are lit

been demonstrated²² that melatonin suppression through LAN exposure renders the drug Tamoxifen totally ineffective in treating breast cancer.

The hypothalamus is responsible for regulating homeostasis and has numerous melatonin receptors. It regulates body temperature, blood pressure, and endocrine functions. The hypothalamus secretes hormones that act upon the adenohypophysis (anterior pituitary) which in turn stimulates the thyroid, adrenals and reproductive organs to release their own hormones. Sleeping in natural darkness, and therefore melatonin production, consequently affects the functioning of the whole body, including the menstrual cycle in women²³. If the hypothalamus does not receive sufficient melatonin, as a result of exposure to light at inappropriate times, then its ability to regulate the endocrine system will be impaired²⁴. Since it is confirmed that exposure to light at night causes circadian disruption and compromised melatonin production, it has been suggested that this may have a rôle²⁵ in the incidence of ADHD in children. This is a condition that may continue into adult life. Children affected by autistic spectrum disorders often suffer from disturbed sleep suggesting that they have a problem with melatonin production²⁶. Since exposure to lighting at night is known

to suppress melatonin production, excessive exposure can only aggravate their condition.

Premature babies are babies born before the full term of thirty-nine weeks has elapsed, being effectively fœtuses that have been born early. Light at night may damage their biological clocks²⁷. Consequently the régime under which they are kept has to match the inside of the womb as closely as possible. They are still developing, so they are kept in a régime of light and darkness to facilitate the development of normal circadian rhythms. This would not happen if they were illuminated twenty-four hours per day.

Another problem that has been linked to intrusive light pollution is myopia²⁸. Children and young people sleeping in bedrooms illuminated by street lights may end up short-sighted. Children sleeping in bedrooms illuminated by night-lights may likewise be affected. In order to avoid this, children should be encouraged to sleep in the dark, and thick curtains installed to prevent obtrusive lighting entering the bedroom. In the long term, this can be prevented by restrictions on the height of street lights and the use of full cut-off luminaries, so that the light does not intrude into bedrooms.

Flashing signs are often used in advertising and have been known to precipitate epileptic fits in some people with photosensitive epilepsy. Frequencies of between 5 and 30Hz have been known to induce seizures. If flashing signs are deemed necessary then the frequency needs adjusting to avoid triggering photosensitive epilepsy. This is because there is a risk of flashing signs inducing epileptic fits in drivers. If a flashing advertising sign induces a fit in a driver, then the effects could be fatal, consequently it would be better if the practice of displaying flashing signs is discontinued. Defective fluorescent tubes are known to flicker, and these can have the same effect.

It is now known that light at night contributes to air pollution. The glow emitted by city lighting is now understood to interfere with chemical reactions that clean the air of pollutants discharged by motor vehicles and factories²⁹. Nitrate radicals in the air break down molecules that contribute to smog and ozone, but the energy created by night-time lighting destroys them leaving the pollutants unaffected. Such pollutants in the air are known to exacerbate medical conditions such as asthma, bronchitis, emphysema and cystic fibrosis.

Much of the energy used for lighting is produced by the

combustion of fossil fuels, resulting in the formation of nanoparticles. They are also formed in large numbers when energy is produced by the incineration of organic waste. Nanoparticles are minute particles about 10μ across that can penetrate the body by inhalation and through the gastrointestinal tract. The deposition of nanoparticles inside the lungs can lead to inflammation, injury of epithelial linings, and pulmonary fibrosis. They have even higher deposition efficiencies in those already suffering from asthma and chronic obstructive pulmonary disease, thereby making their conditions worse³⁰. Nanoparticles can enter the gastrointestinal tract by the involuntary swallowing of material removed from the bronchi by mucociliary action³¹. The circulatory system can then distribute them all round the body, after which they can cross the blood-brain barrier and the placenta³². It has been suggested that they can even be absorbed through the skin, though this is still debated. Nanoparticles are hazardous because they can penetrate cell membranes and interfere with physiological processes inside cells. In addition, they have been implicated in the distribution of toxins around the body. Since at least 19% of energy production is consumed by lighting it follows then that lighting will be responsible for a measurable proportion of

nanoparticle formation. Consequently public lighting is a major contributor towards ill health on a global scale.

Excessively bright or badly aimed lighting causes glare. Glare can take two forms³³:

i) Disability Glare.

This results from the physiological response of the eye to bright light sources resulting in the loss of visibility due to a bright light source in the field of view.

ii) Discomfort Glare

This does not hamper vision on a short term basis, but discomfort from bright light sources in the field of view can become irritating, distracting or even painful, leading to mental fatigue, headaches and tension. In drivers this can lead to reduced concentration affecting road safety. The human eye is not designed to look directly at light, but instead to see with light³⁴.

Normally the eye adapts to the darkness at night, but bright lights destroy the visual purple (rhodopsin), the photosensitive pigment found in the retina. The person has been dazzled. Once dazzled, anyone approaching a bright light is visually impaired to the point that his/her eyes may not re-adjust for some time. This can be dangerous if driving a vehicle, or simply walking towards a

bright light source, as the risk of an accident can substantially increase. Better lighting design, especially with new L.E.D. technology can help to alleviate these problems if correctly applied. However, where they have been introduced they have often been found to be excessively bright to the point of discomfort³⁵. As pointed out earlier, L.E.D.s contain a high blue component that can suppress melatonin production and also increase their attractiveness to insects³⁶. Excessive exposure can lead to degenerative eye diseases such as age related macular degeneration. To avoid these problems outside lights should be aimed downwards and shielded so the luminaire is not visible, thereby guaranteeing that the light only shines on the area intended to be lit. If they are motion operated, then the light only comes on when needed. In order to reduce melatonin suppression, phototoxicity³⁷ and attractiveness to insects, low colour temperature amber coloured L.E.D.s should be introduced.

Glare from badly designed street lighting can adversely affect older people who are visually impaired by cataracts³⁸. They may be able to see well enough in daylight, but when confronted by unshaded street lighting at night they see bright blobs around the lights that obscures the view of the area around them. Driving in

unilluminated areas is less of a problem. Many older people suffer from cataracts to a greater or lesser extent so this problem of lighting affecting their vision may make them reticent about venturing out after dark.

It is often said that road lighting has significant benefits in that it reduces the accident rate at night³⁹. However it may lull drivers into a false sense of security, encouraging them to take less care and drive faster in areas that are lit⁴⁰. Any perceived advantage of having street lighting is therefore nullified and the incidence of accidents in illuminated areas may well increase.

Excessive exposure to light has been implicated in obesity, though this may at first sight seem difficult to believe. The seasonal lengthening of the night in late summer and autumn can be masked by artificial lighting. Extended exposure to lighting mimics long summer nights that is now known to cause cravings for carbohydrates. This behaviour is normal in that it encourages a build-up of body fat in readiness for winter. However, if present all year long this is no longer advantageous as the winter never comes⁴¹. This results in excess body mass and obesity in susceptible individuals, that can lead to depression, Type II diabetes and heart disease. This has been further backed up by a

study in the UK⁴² that suggests a significant connection between LAN exposure from light penetrating bedrooms, and obesity. These results reinforce findings from animal experimentation and warrant further investigation.

Lighting has been reported to have had some weird effects. Aberrant behaviour has been reported in Australian juveniles lying prone on the grass⁴³, staring close range at floodlighting installed to illuminate trees (fig 6) in a park outside Melbourne. This craze was akin to glue-sniffing behaviour seen elsewhere. It was reported on several occasions, and may well have occurred in other locations but not observed. Such lighting contains levels of short wavelength light that is highly damaging to the eye at high intensities, and led to the recommendation that the lighting be removed immediately. This set a precedent against the use of such lighting elsewhere. This type of lighting is an example of "vanity lighting," since it is decorative and doesn't serve any useful purpose. It also has the added drawback that it is harmful to the wildlife that may reside in the trees, and also to the trees themselves.

Light at night, and the light pollution resulting from it, have consequently become a true public health issue⁴⁴ for both humans



Fig 6. Example of an illuminated tree, The Cedars Nursing Home, Bowdon, Cheshire, England, 2012. Note that the building is also floodlit. Image: C. Henshaw.

and for all living things. Because of it, shift work was listed as a "probable" carcinogen by the World Health Organisation in 2007.

Unfortunately, the excessive use of lighting has not been shown to have any beneficial effects. More and more scientists and health-care professionals are now becoming aware of the dangerous effects of light pollution caused by light at night. Though it has been regarded by some as a problem for over forty years, it is only recently that it has been recognised as such by the medical profession. Its long term effects are unknown. The lighting industry does not help, since it will naturally promote its own

products and may be resistant to arguments pointing out their deficiencies. This may take many years to overcome. It exploits the natural fear of the dark and the belief that more and brighter lighting = less crime. It is now well established, however, that this equation is not true.

The Lighting Industry

The lighting we use is provided by the lighting industry and municipal lighting departments. Unfortunately the lighting industry needs constraint and needs to be regulated. It always promotes the view "Light is good, darkness is bad." The standards it has imposed are all wrong. That is why we have a problem with light pollution, so those who cause the problem should not be allowed to write the rules⁴⁵. Darkness at night is normal, and is not only essential for ourselves, but also for the health and well-being of all living things. The lighting industry continues to promulgate urban myths that more and brighter lighting = greater security and less crime⁴⁶. It is now well established that these ideas are not true⁴⁷. The industry perpetuates these myths in order to maximise profits. In addition it is known that criminality almost drops to zero during power failures, as can be seen in Bangladesh where as many as two power failures (through load shedding) occur every night. Police.

officials reported almost zero criminality during another power failure in Auckland, New Zealand^{48,49}. Consequently, one is actually safer under a blanket of darkness, though carefully aimed, motion operated security lighting can prove a deterrent to intruders. What is not generally known, however, is that most crime occurs in daylight. Therefore criminals need light⁵⁰. This view is reinforced by the fact that thefts from gardens increase during long summer evenings⁵¹. Unfortunately increasing lighting encourages people to behave at night more as they would during the day. Therefore more lighting = more crime, so high crime areas coincide with those that are most intensively lit.

There are far too many people among those who make, choose and install lighting whose lack of appreciation of the "downside" of lighting, hinders progress. There isn't a conspiracy of lighting professionals and council employees who are out to do harm - they are just ignorant. So our health is suffering as a result. They don't care about the damage they cause as they have their own ill-conceived agenda, and they don't have to accept responsibility for the problems caused by unnecessary LAN. Consequently they need to be regulated by a body made up of people without any vested interests in the industry. This body should serve to protect the

environment, monitor lighting schemes to ensure that standards are adhered to, and to curtail any abuses. It should have the power of veto, and serve as an adjudicator to whom people can complain when bad lighting affects them, and from whom their complaints can be redressed.

Unfortunately people are demanding more light because very often they feel insecure. The well-being of the environment is demanding less. As was mentioned earlier, darkness at night is normal and essential for the well-being of humans, animals and plants. Therefore society should learn to adapt and accept darkness as part of the natural order of things. A universal culture change is required, just as there was with the wearing of seat-belts, drink-driving, and smoking in public places. Obtrusive lighting, irrespective of where it comes from, is therefore antisocial.

Vanity Lighting

One aspect of antisocial lighting is vanity lighting. This consists of all lighting that does not serve any useful purpose, including illuminated advertising in residential and rural areas, illuminated regeneration follies, [i.e. illuminated public "art," (fig 7) skybeams (fig 8) and lasers], decorative lighting, floodlit churches, mosques (fig 9) and other public buildings. Such lighting

adds to the pre-existing levels of light pollution already created by street and security lighting. As such it is damaging to both humans and the environment, and is totally inappropriate outside the centres of towns and cities. The incidence of breast cancer through circadian disruption may well increase in residential buildings that are illuminated at night⁵².

Illuminated regeneration follies are civic or commercial schemes of one kind or another that have become increasingly common over the past ten years or so. They are damaging because they cause an unnecessary intrusion into the night sky and the local environment. They are usually expensive and don't serve any useful purpose hence the term "folly," used in its original context to describe fake ruins constructed on landed estates during the Eighteenth Century). They are often constructed under the pretext of regenerating depressed areas, or promoting commercial interests. Unfortunately, many of these pointless schemes are simply vanity projects driven by local councillors on an ego trip⁵³. One such scheme was recently overturned by public opposition and saved the national exchequer around £245,000. Another, costing £1,300,000, had its plans for floodlights and skybeams overturned by local opposition.

Recommendations

Of course some lighting at night is needed as a few people need to work and move around at night. However, lighting should only be

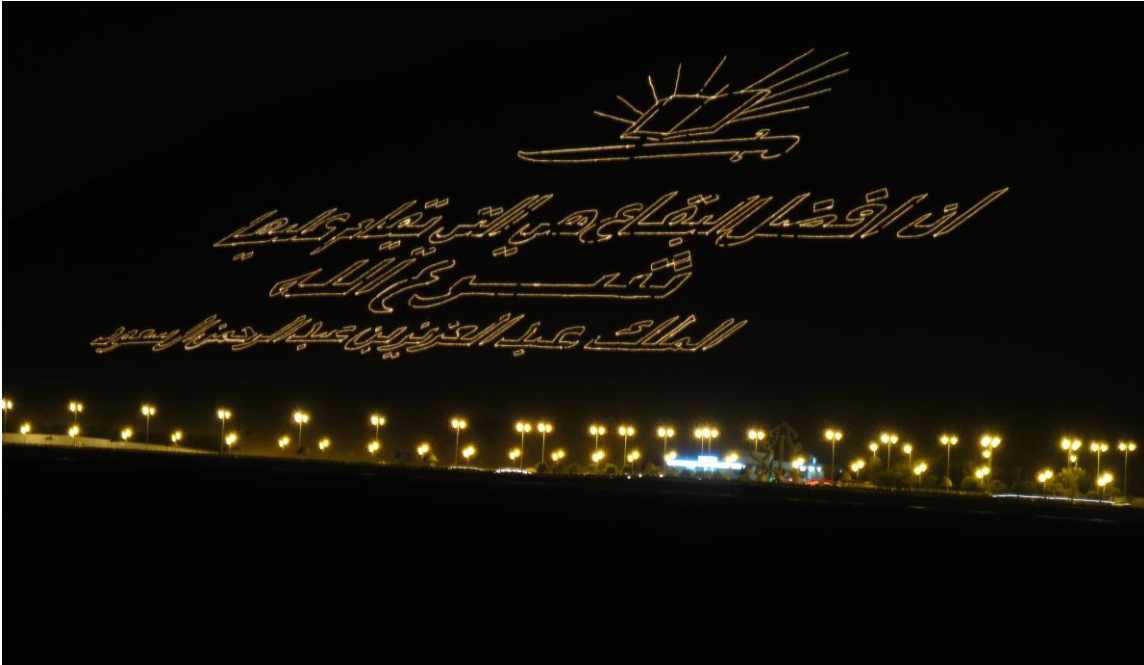


Fig 7. Illuminated graffiti on hillside, Haql, Kingdom of Saudi Arabia. Image: C.Henshaw.

installed sparingly, where needed, when needed, and in the correct amounts. It should only be applied using smart technology that has specifically been designed for the purpose. Much of our existing lighting can be eliminated without any serious effect, and lights switched off when they are not needed. Those responsible for community planning should prevent over-lighting. In order to facilitate this, exterior lighting should be subjected to stringent planning control. Industry, commerce, local government and domestic consumers should be encouraged to use efficient lighting and



Fig 8. Three gyrating skybeams emanating from a mosque, Istanbul 2012. Image: C.Henshaw.



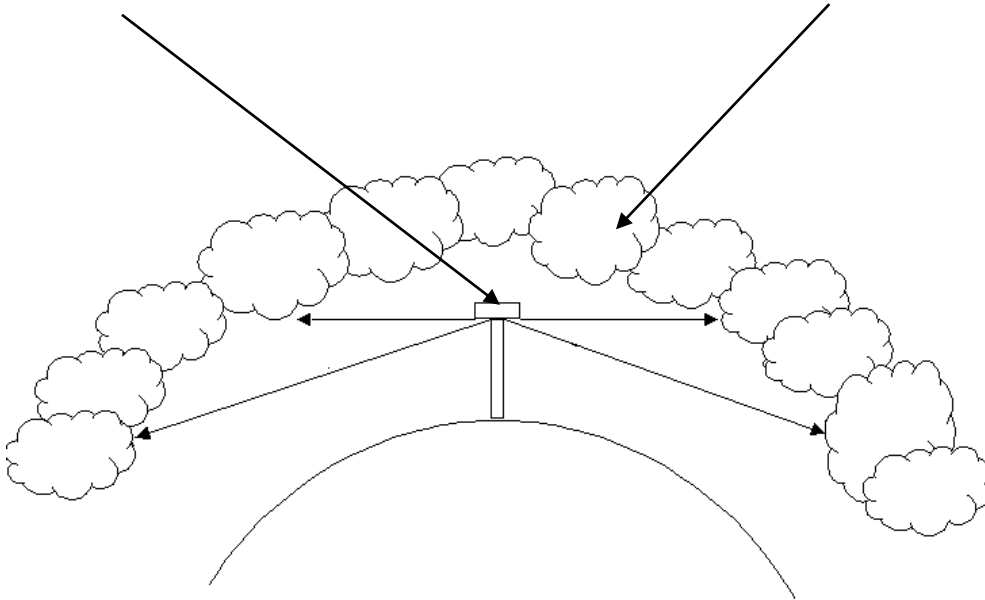
Fig 9. Floodlit Buildings: illuminated mosque, Istanbul 2012. Image: C.Henshaw.

minimise energy wastage, and light pollution should be made a statutory nuisance in law. This has already happened in some countries, and it can pave the way for litigation in cases of abuse. To reduce sky glow and light nuisance, street lighting should be full cut-off, or better. Standard full cut-off lighting does have certain drawbacks (fig 10). Light travels in straight lines, but the Earth's surface does not (figs 10 and 11). When long bridges are constructed, the engineers have to take into the consideration the curvature of the Earth, which even over distances of several kilometres becomes significant. The towers on the New York Verrazano Narrows Bridge are 4.5cm further apart at the top than they are at the bottom⁵⁴. So it is with lighting. With light travelling in straight lines, the further away from the light source one travels, the further the Earth's surface curves away from the light. However, the cloud ceiling hovers parallel to the Earth's surface and curves with it. Consequently it may still become illuminated by large numbers of full cut-off lights that will be visible at a distance (up to 200km - fig 11). To avoid this problem lights should be better than full cut-off to prevent leakage into the sky). In this type of lighting the luminaire is shielded by a flat glass shroud, oriented parallel to the ground

Fig 10: Why 90° Full Cut-Off Lighting still causes light pollution

The cloud ceiling is curved, being parallel to the curvature of the Earth's surface. However, with light travelling in straight lines, 90 degree full cut-off lighting such as may exist in large numbers in a city will collectively illuminate the cloud ceiling at a distance as, from this vantage point, the undersides of the lights will become exposed. To prevent this from happening, the lighting should be better than 90 degree full cut-off with the luminaire countersunk into its housing to eliminate any sideways spillage of light into the environment.

Full cut-off street light. Cloud ceiling not directly illuminated above light.



and not tilted. The luminaire should be countersunk into its housing so it cannot be seen from a distance. Such lighting does not allow light to leak out above the horizontal, so should not penetrate bedrooms located above the light. Nor should it illuminate the cloud ceiling at a distance. If the lights are hooded and motion operated, then the situation can be improved even

further, as light nuisance will then be minimised. *If the luminaire is visible from a distance, then it is a bad light.*

Restrictions can be imposed on the wattage and luminance of exterior lights, and height restrictions on street lights. No street light in a residential area should exceed first-floor

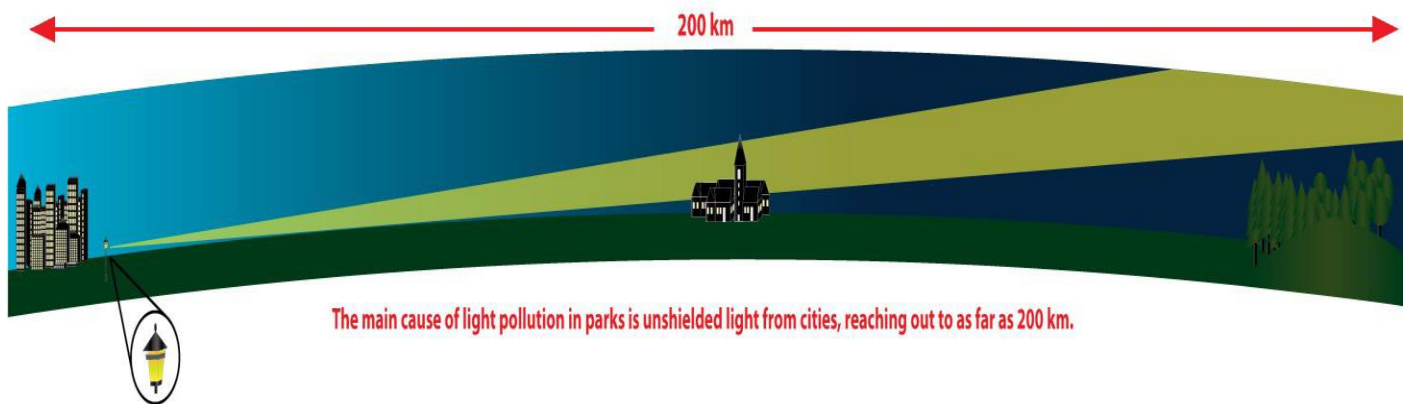


Fig 11. Light can reach out as far as 200km as this illustration shows⁵⁵. Any clouds above the trees at the far right will be illuminated, even though the light sources in the city at the far left are below the horizon to an observer on the ground. One street light will have minimal effect, but the combined effect of thousands will be cumulative. Image credit: Andrej Mohar.

height, to prevent light intrusion into bedrooms. Motion operated bollard lighting would be more appropriate in residential areas with a low risk of vandalism. All exterior lighting should be shaded and aimed downwards to prevent light nuisance.

All-night lighting should only be permitted in city centres and major thoroughfares in suburban areas, where people are constantly active. Minor roads in suburban areas should operate on an 11 p.m. till dawn curfew to give the environment time to recover. *In winter, schools and businesses can adopt a winter timetable*

starting work in daylight and finishing later. This obviates the need for people to get up in the dark and as a consequence, early morning lighting. This will also lead to a reduction in accidents.

These measures will confer darkness, and people will find that they will sleep better. Local government is under no responsibility to illuminate streets for people who choose to be out after that time. The onus is on them to provide their own lighting, and they should use a torch. Lighting is not an option in rural areas so as to maintain the distinction between town and country. *Municipal lighting authorities should be under an obligation to remove obtrusive lighting from outside homes if the householders don't want it and insist on its removal.*

Security lighting should be motion operated (fig 12) so it only comes on when needed, and at all other times remains switched off. In this way it will be a much greater deterrent than lighting that is on all the time. Such lighting should always be aimed downwards and hooded to avoid light nuisance. In this way the light only shines on the target area, and if correctly installed, does not cross property lines. An outdoor domestic security light of 400 lumens, (equivalent to a 9W CFL bulb or a 40W incandescent bulb)



Fig 12. Though not perfect, this motion operated floodlight is designed to minimise light pollution by functioning only when it is needed. It only directs light where it needed, and no more than is necessary. Credit: <http://www.tesco.com/direct/byron-halogen-anti-light-pollution-security-light-es128/209-0961.prd?pageLevel=&skuId=209-0961>

would be perfectly adequate for this purpose⁵⁶. Lighting that does not meet these specifications (fig 13) should be phased out. This includes excessively powerful halogen fittings that are all too common in domestic and commercial situations, and used by municipalities in vanity lighting to illuminate public buildings and monuments.

Unnecessary lighting that does not serve any useful purpose should be banned in (or if visible from) residential, suburban and



Fig 13. A typical bad light. This type of light fitting is responsible for much of the glare and light trespass described earlier. It emits more light than is necessary, while a substantial amount leaks out into the sky. Credit: http://www.niesoh-lighting.com/wp-content/uploads/2013/06/400W-Halogen-Floodlight_large.jpg

rural areas. This will include all those types of vanity lighting mentioned earlier. Lighting in buildings that are not going to be functional at night should always be switched off. Interior lighting can also be motion operated to good effect.

Conclusions

Light at night is a serious environmental problem that has a number of medical implications. It contributes to global warming that may encourage the spread of tropical diseases into areas where they previously did not exist or had been eradicated. It disturbs

circadian rhythms, leading to neurodegeneration and premature aging. It can also disturb the endocrine system and affect the menstrual cycle in women. It has been linked to short sightedness in children and may also lead to ADHD. Children (and adults) should sleep in dark bedrooms where street and security lighting is not allowed to penetrate. Light at night has been linked to breast cancer in women and prostate cancer in men. The incidence of breast cancer may increase if residential properties are illuminated at night, so this form of vanity lighting should be strongly discouraged, if not, banned. It can cause depression, and disturbed sleep, causing fatigue and impaired thinking that can lead to accidents (a very serious problem for emergency workers such as nurses, firemen and the police). It also contributes to air pollution that is known to exacerbate a variety of respiratory complaints.

LAN can be greatly reduced by introducing more modern full cut-off types of street lighting, or better. Curfews should be imposed on street lighting in residential areas in order to maintain the balance between day and night. These were standard practice up till 1969, but once again they are being considered as the economic constraints of energy wastage begin to bite. New legislation can be

introduced to reduce light nuisance by controlling the type of exterior lighting that can be used at night. This should include the compulsory use of motion operated security lighting, and height restrictions on street lights in residential areas.

Improved lighting design can help to reduce glare, especially with new appropriately designed L.E.D. technology. This will alleviate the physiological and psychological problems resulting from glare, thereby improving road safety and reducing accidents. LED lighting, however is a double edged sword, since it contains significant amounts of light towards the blue end of the spectrum, but this can be alleviated by the introduction of amber coloured LEDs.

Controls on obtrusive lighting may be unpopular at first, but *the essence of good governance is to know what the people want, and to know what the people need, and to have the wisdom to understand the difference.*

Redressing the problem of unnecessary light at night can now be seen to have substantial benefits. With the elimination of unnecessary lighting, not only will our health and general well-being improve, but we will also be protecting the environment by preventing energy wastage, saving money, and reducing the carbon dioxide emissions responsible for climate change and global

warming. Money spent on excessive and unnecessary lighting would be better spent on health, education and welfare. In addition it could also contribute to the more appropriate regeneration of depressed areas and as a consequence the alleviation of poverty and deprivation.

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1) The Lighting Industry: if they consider the findings compromise their profits and jobs.

2) Municipal councils: since their lighting practices are called into question.

3) Businesses involved in the marketing and application of inappropriate forms of lighting.

Ethical approval: none required.

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