Public Health by Design

Trafford LED Street Lighting Health Impact Assessment

2014 Follow Up Review Report

DRAFT REPORT

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PHD QUALITY ASSURANCE

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Executive Summary

Introduction

ES.1 This Review Report is a review and follow up of the June 2013 Trafford LED Street Lighting Programme Health Impact Assessment Report (2013 HIA Report) that was commissioned by Trafford Council.

ES.2 The aim of this report is to provide an update to the findings of the 2013 HIA Report in light of new scientific reviews and/or journal articles as well as any other material that has been identified by Trafford Council since the 2013 HIA Report was published.

Scientific evidence on the health effects of LED street lighting

ES.3 This review has found no evidence that LED street lighting, including 'cool' white and blue-rich white LED street lighting, has any additional health and wellbeing effects beyond that found for artificial lighting in indoor or outdoor settings in general.

ES.4 Most importantly while 'cool' white light and blue-rich white light are discussed in the literature there is no clear consensus on what this means in terms of Correlated Colour Temperature (CCT) measured in Kelvins (K). Hence there is no consensus on what level of lighting in terms of Correlated Colour Temperature (CCT) is optimal.

Health impacts of Trafford LED street lighting

ES.5 Any proposed introduction of LED street lighting in Trafford, and ad hoc replacement of existing lighting, has, overall, no (neutral) or a minor positive health and wellbeing impact for the residents, workers and visitors of Trafford compared to the existing non-LED type of street lighting being used.

ES.6 The health impact of white LED street lighting, including 'cool' or blue-rich at 5700K, is likely to be similar to that of existing non-LED lighting because the contribution of the exposure of residents to street lighting will be a small proportion of their overall exposure to artificial lighting indoors and other types of lighting outdoors.

ES.7 Hence, there is no scientific evidence supporting the need to remove the LED street lighting currently in place in Trafford.

Health impacts of mixed LED and sodium lighting

ES.8 Though there is likely to be a difference in the quality/characteristics of light generated between the LED and sodium lighting, the health impact of mixed LED and sodium lanterns, as indicated in ES.3, is likely to be similar to that for sodium lighting on its own.

Mitigation and enhancement measures

ES.9 The general recommendations of the 2013 HIA Report continue to be applicable with minor amendments. No recommendations on the specific design, types or levels of LED street lighting would be appropriate given the lack of evidence that LED street lighting has any adverse health impacts.

Street Lighting Maintenance Policy

ES.10 Trafford Council's Street Lighting Maintenance Policy was reviewed in light of the scientific evidence and the references to LED street lighting are judged to be in line with the evidence and unlikely to cause adverse health impacts.

2 Introduction

2.1.1 This Review Report has been commissioned by Trafford Council.

2.1.2 This Review Report is a review and follow up of the June 2013 Trafford LED Street Lighting Programme Health Impact Assessment Report (2013 HIA Report) that was commissioned by Trafford Council.

2.1.3 The aim of this Review Report is to provide an update to the findings of the 2013 HIA Report in light of new scientific reviews and/or journal articles as well as any other material that has been identified by the review team and Trafford Council since the 2013 HIA Report was published.

2.1.4 The objectives of the Review Report were to:

i. Provide an update of the latest research on Light Emitting Diode (LED) street lighting and human health taking account, where possible, of the technological advances in LED technology.

ii. Review, challenge and, where appropriate, update the literature review findings of the 2013 HIA Report in light of new research.

iii. Review, challenge and, where appropriate, update the recommendations on the mitigation measures presented in the 2013 HIA Report in light of new research.

iv. Consider, in addition to whole street LED lighting, whether there are any potential health impacts arising out of the ad hoc replacement of standard luminaires with LED luminaires, i.e. when existing lighting fails/stops working, as part of Trafford's Street Lighting Maintenance Policy (around 3.2% of the existing stock has been replaced with LED's).

v. Consider whether there is any justification for the removal of existing LED luminaires on the grounds of potential human health impacts.

vi. Consider, the statements on 'cool white' luminaires within the procurement and street lighting maintenance policy.

3 Methodology and Scope of this Review

3.1 Introduction

3.1.1 The core of this report is a literature review and summarising of key findings from literature that has been published since June 2013.

3.1.2 There were discussions with the Trafford Director of Public Health in terms of informing the scope of the report, the issues raised by local people in relation to the LED Street Lighting Programme, the local community health context and the existing and proposed LED lighting procurement and maintenance scheme.

3.2 Evidence review

3.2.1 This report searched and where found reviewed the following sets of documents.

3.2.2 Key secondary scientific research reviews and primary research articles, since June 2013, on the actual and potential health effects of:

- LED street lighting
- LED lighting
- Artificial light

3.2.3 Older material identified by Trafford Council that they wished to be explicitly reviewed as part of this Review Report.

3.2.4 Research studies and surveys of LED street lighting pilots and programmes.

3.2.5 Past HIAs on street lighting and LED street lighting.

3.2.6 See Appendix A for more details on the bibliographic databases searched and key words used.

3.3 Review of community feedback on existing and proposed LED lighting

3.3.1 A review and synthesis of the community feedback on existing and proposed LED lighting was undertaken.

3.4 Review of surveys of what other local authorities are using LED street lighting and of residents in areas where LED street lighting is being implemented

3.4.1 A review and synthesis of publically available surveys on local authority's use of LED street lighting and residents views on LED street lighting was undertaken.

3.5 Review and challenge of the findings of the 2013 HIA Report

3.5.1 The 2013 HIA Report was reviewed in light of the evidence review and any update to the findings of the 2013 HIA Report have been presented and discussed. Where the findings of the 2013 HIA Report are judged to still be current then the reasons for this are discussed.

3.6 Review and challenge of the recommendations for mitigation measures set out in the 2013 HIA Report

3.6.1 The 2013 HIA Report was reviewed in light of the evidence review and any update to the recommendations for mitigation measures set out in the 2013 HIA Report have been presented and discussed. Where the recommendations for mitigation measures set out in the 2013 HIA Report are judged to still be current then the reasons for this are discussed.

3.7 Review of evidence on the use of LED lighting and existing sodium lighting

3.7.1 A specific key word search and review was undertaken on the health impact of mixing LED lighting with existing sodium lighting as existing lighting failed.

3.8 Limitations of this Report

3.8.1 The main limitations were:

- This was a non-systematic[1] review of the key current scientific literature in an emerging field. The majority of the literature has focused on artificial lighting in

[1] This review was systematic in the general sense in which the word is used but not in the epidemiological sense as it reviewed all types of scientific research evidence and some non-scientific sources and did not use a pre-defined set of eligibility criteria. This is because systematic reviews have much stricter criteria for what they

general and various types of lighting including LED, fluorescent and incandescent lighting much of it in experimental settings using animal models. There was little specific literature on LED street lighting in isolation and human health.

consider as good evidence and good research design. This generally means that the numbers of even scientifically peer-reviewed studies that are reviewed in a systematic review tend to be much smaller than the whole literature in a field of study.
http://www.thecochranelibrary.com/view/0/AboutCochraneSystematicReviews.html

4 Policy Context and Implementation of LED Street Lighting in the UK

4.1 Introduction

4.1.1 This chapter presents any changes to the policy context on LED street lighting in the UK and any other relevant material relating to the policy context and implementation of LED street lighting in the UK.

4.2 Policy Context

UK

4.2.1 There have been no material changes in the UK policy context on LED street lighting since the 2013 HIA Report.

Australia

4.2.2 Trafford Council received information that Standards Australia had or were considering a change in their lighting standard to include a discussion and standard on the health effects of blue-rich white LED street lighting.

4.2.3 The Review Team found no mention of the human health effects of blue light, blue-rich white light or of LED lighting in the current standard AS/NZS 1158.6:2010. The only mention of blue LED lighting is the following:

- "The increase in the blue content of light sources is of great concern to astronomers."

4.2.4 A Google search identified a consultation submission from the Southern Sydney Regional Organisation of Councils (SSROC) to a consultation by Standards Australia on revising the standard in 2013. They asked for the above sentence to be changed and provided a commentary on why this change was necessary including reference to some literature on the health impacts of LED street lighting. However, the SSROC's proposed changes have not been taken up by Standards Australia.

4.2.5 The above standard is again under consultation to modify it in line with CEI/IEC 60598-2-2:2002 *Luminaires – Part 2-3: Particular Requirements – Luminaires for Road and Street Lighting*. The draft standard is DR SA/SNZ TS 1158.6.2014.

4.2.6 The Review Team found no mention of the human health effects of LED or of blue-rich white light lighting in the international standard CEI/IEC 60598-2-2:2002. Therefore it is likely that any changes that Standards Australia will be making when this current consultation ends in December 2014 will not be about the human health effects of LED or blue rich white lighting.

4.3 Numbers of councils that have implemented LED street lighting in England

CAMPAIGN TO PROTECT RURAL ENGLAND SURVEY

4.3.1 The Campaign to Protect Rural England (CPRE) undertook a survey that they published in April 2014, *Shedding Light: a survey of local authority approaches to lighting used in England*. The focus of the survey was on: whether local authorities have adopted new or revised lighting policies as a result of the National Planning Policy Framework (NPPF); the type of lighting that is used by local authorities and how decisions are made on whether to install new or replacement lighting; whether local authorities have introduced schemes for switching off street lights or installing dimming technology to offer varied levels of lighting during the hours of darkness.

4.3.2 83 local authorities responded to the survey - 17 county councils, 31 district councils, 10 metropolitan borough councils, 18 unitary authorities and seven London boroughs. This represented a 24% response rate. Responses were received from every English region.

4.3.3 Of the 83 Councils that had responded 32 were using LED street lighting. The most common colour temperature of LED lighting was 4000k cited by almost two thirds (64%) of 28 local authority respondents. This is followed by just over a quarter (29%) that used 4100k, then 18% used under 3500K and then 14% who used 3500-3999K. Wakefield Council, in West Yorkshire, said that its current installations fall in the range of 4000k to 5700k and it is 'working to ensure they are in the low end of cool white heading towards neutral.' The London Borough of Islington said it has 'some 5000K as a trial but residents find these too harsh'. Northumberland County Council said that it is using cool white

(6200K) on residential areas and Neutral white (4250K) on traffic areas. This part of the survey is particularly limited (32 council out of just over 350 council in England as a whole) and therefore is not representative of the majority of local councils in England.

4.3.4 It is important to recognise that no council raised health concerns about LED lighting and did not use health impact as a criteria in choosing the type of LED street lighting they were using. The following factors were considered important factors when choosing new street lamps: lamp design, potential impact of lights shining into residential/business premises, energy efficiency, ease of maintenance, colour rendition index (CRI), cost, potential impact of light pollution in the night sky, impact of street lights and columns in the daytime (e.g. street clutter), potential impact of light on wildlife and habitat, ability to control the light centrally e.g. to allow dimming, impact of street lights in open countryside, and impact of street lights in intrinsically dark landscapes e.g. national parks.

4.3.5 A total of 23 local authorities said they were involved in switching off street lights, typically between midnight and 5am, and 32 said they were involved in dimming street lights in their areas. Saving energy was the most important factor for local authorities that were switching off or dimming street lights, followed by cost saving. The reduction of local light pollution was largely viewed as an additional benefit.

4.3.6 The survey has also revealed that communities are much more supportive of dimming street lights than switching them off; 68% were very supportive of dimming street lights compared with only 10% of communities who supported switching off. Although a main concern about switching off or dimming lights is the potential impact on crime levels, no local authority said that there had been an increase in crime or a clear link to adjusted street lighting. Many respondents said that they liaised with the local police about lighting and would make any recommended adjustments.

4.3.7 Many local authorities are upgrading their street lighting to LEDs or white lighting, which could help reduce light pollution levels in the coming years.

5 Scientific Evidence on the Health Effects of LED Street Lighting

5.1 Introduction

5.1.1 The aim of this review of the scientific research literature was to review and challenge the evidence review findings presented in the 2013 HIA Report.

5.1.2 This chapter is split into four sections, key findings of:

- Scientific or other credible reviews (secondary research) on LED street lighting or artificial lighting in general.
- Scientific research on human health effects of LED and artificial lighting as presented through scientific journal (primary research) since June 2013 or where an article has been presented to Trafford Council since the publication of the 2013 HIA Report.
- Research studies and surveys, not identified in the 2013 HIA Report, of the piloting or use of LED street lighting and the concerns, if any, that have been raised.
- Past HIAs on proposals to implement LED street or other LED lighting.

5.1.3 References within quoted extracts have been removed to aid clarity of reading.

5.1.4 Statements within square brackets [] have been added to make a point, clarify or amend a typographical error in the original. Bold emphasis to certain quoted extracts has been added to highlight a particularly key point.

5.1.5 A more detailed description of the approach used to identify literature in this HIA is provided in Appendix A.

5.2 Review reports

5.2.1 No review reports since for 2013 or 2014 were identified. Journal articles and reviews are discussed in Section 4.3.

5.2.2 Two additional reviews were identified from 2009 and 2010, none of these were as comprehensive as the main reviews discussed in the 2013 HIA Report:

- Visibility, environmental and astronomical issues associated with blue-rich white outdoor lighting. (2010). International Dark Sky Association.
- Blinded by the light?. (2009). Campaign for Dark Skies (CfDS). British Astronomical Association.

5.2.3 One book on light pollution published in 2013 was identified:

- Light pollution as a new risk factor for human breast and prostate cancers.

<u>VISIBILITY, ENVIRONMENTAL AND ASTRONOMICAL ISSUES ASSOCIATED WITH BLUE-RICH WHITE OUTDOOR LIGHTING. (2010).
INTERNATIONAL DARK-SKY ASSOCIATION (IDA)</u>

METHODOLOGY

5.2.4 The methodology for this review is not presented in the report. Nor are the authors listed. However another document *Seeing Blue* states that this was a white paper for which IDA convened a panel of 16 experts in Tucson, Arizona to evaluate concerns about blue-rich white light (BWRL) in 2009. It was not stated who the experts were. The draft white paper was released to a select audience in early 2010 and feedback from this informed the final version of the white paper.

5.2.5 The focus of the report is on blue-rich "cool white' LEDs that have a high proportion of energy emitted below 500nm (nano-metres) with spikes at the 450-460nm range.

OVERALL CONCLUSION

5.2.6 The review states that while blue-rich light may be advantageous to human vision it may have the following issues:

- Pupillary response: blue-rich light causes incrementally smaller pupil sizes than yellower light and this may reduce visual performance for tasks closely relate to foveal vision [central vision i.e. detailed tasks] or photopic luminescence (well lit or daylight vision).
- Adaptation: blue-rich light increases adaptation time required for maximum scotopic sensitivity (low light vision) and inhibits dark adaptation/suppresses

scotopic response. "The implications in a real world setting with glare sources, poor uniformities, harsh transitions, wide-ranging illumination levels and adaptation time scales are important to consider and remain poorly understood. The vision advantages of blue light shown in laboratory experimental settings with dark adapted subjects or in simplified roadway designs does not translate well for some applications."

- Glare: blue-rich light can produce more glare which can lead to discomfort, blinking and squinting and may reduce visual performance.
- Ageing eyesight: blue-rich glare when present is likely to affect older people more because of their poorer eyesight leading to more sensitivity.
- Health effects: the review states that "While a **firm connection between outdoor lighting and cancer has not yet been established**, if true it is clear that the blue component of such light would be a greater risk factor." The review before this statement provides a quote from a journal review article which focuses on light indoors and Light At Night (LAN) and not specifically on blue-rich light. "The level of impact [of lighting] on life on the planet... is only now beginning to be appreciated. Of the many potential adverse effects from LAN and circadian disruption on human health, the most evidence to date is on breast cancer. No single study can prove cause and effect, as neither can a group of studies of only one of the factors cited above. However, taken together, the epidemiologic and basic science evidence may lead to a 'proof' of causality (i.e. a consensus of experts). If so, then there would be an opportunity for the architectural and lighting communities, working with the scientific community, to develop new lighting technologies that better accommodate the circadian system **both at night and during the day inside buildings**." [Bold emphasis added.]

5.2.7 "The **current state of knowledge regarding the health effects of light at night, and in particular blue-rich light at night, permits no firm conclusions**. Yet, the clear linkage between short-wavelength emission, the blue-sensitive response of the photoreceptors involved in the human circadian system, and the suppression of melatonin production by short-wavelength emission, indicates at least that widespread

use of blue-rich light sources at night should be considered with caution. There is an urgent need for further research in this area, due to the potentially grave impacts hinted at by much research." [Bold emphasis added.]

BLINDED BY THE LIGHT?. (2009).
CAMPAIGN FOR DARK SKIES (CFDS). BRITISH ASTRONOMICAL ASSOCIATION.

METHODOLOGY

5.2.8 No methodology is stated. As with most of the review in the 2013 HIA Report the focus of this review is on light at night, including dim light at night, in general both indoor and outdoors not specifically LED lighting.

OVERALL CONCLUSION

5.2.9 "While inappropriate light exposure and circadian disruption due to shift-work and jet-lag are well defined, the effects of inappropriate light exposure while living on more regular schedules have only just started to be explored. Given that dim light is capable of stimulating effects on human physiology, we cannot consider dim light an inert stimulus and must keep it in mind when reviewing the appropriateness of light environments.

5.2.10 Unnecessary horizontal and vertical street lighting permeates living spaces, particularly bedrooms. This light intrusion, even if dim, is likely to have measurable effects on sleep disruption and melatonin suppression. Even if these effects are relatively small from night to night, continuous chronic circadian, sleep and hormonal disruption may have longer-term health risks. Short- and long-term measures to reduce light pollution are therefore likely to have a beneficial effect on human health, in addition to reducing energy demands. While we have yet to understand fully the environmental and health impact of being exposed to light at night, the data to date suggest a detrimental effect of prolonged exposure to light at night.

LIGHT POLLUTION AS A NEW RISK FACTOR FOR HUMAN BREAST AND PROSTATE CANCERS. (2013).
HAIM A AND PORTNOV BA. SPRINGER.

METHODOLOGY

5.2.11 The book attempts to answer the following questions by reviewing the scientific research literature: Do these nightlight-enabled alterations in our life styles and newly introduced

light sources interfere with our ''preprogrammed'' daily cycles? Can these changes and newly introduced LAN [Light At Night] sources potentially suppress MLT [Melatonin] production, weaken our immune system, and thus expose us to additional health risks, such as BC&PC [Breast Cancer and Prostate Cancer]?

OVERALL CONCLUSION

5.2.12 "Artificial light which reaches human eye retina during nighttime reduces the nocturnal production of the pineal melatonin (MLT) hormone. Blue short-wave illumination, commonly used today for both indoor and outdoor lighting, is most effective in MLT suppression. Impaired secretion of MLT (a hormone with tumor inhibiting properties) may result in estrogen receptor affinity and thus increase the susceptibility of humans to BC&PC."

5.2.13 "If the ''LAN-MLT'' hypothesis is correct, then any person exposed to high intensity of artificial light during nighttime (when MLT is chiefly produced) is likely to be in a high risk group for BC&PC. First and foremost, such population cohorts include **nighttime shift workers (that is, hospital physicians, nurses, bus drivers, undertakers, cashiers and shop assistants, flight attendants, etc.). This ''high risk'' group may also include any person who works, studies, or regularly attends places of entertainment late at night, as well as people suffering from insomnia or sleep disturbance, and/or persons sleeping with full lights on during nighttime**. [Bold emphasis added.]

5.2.14 "The second mechanism of LAN influence (that is, the LAN-DRD [Light At Night – Daily Circadian Rhythm Disruption] path) is less well researched and understood. According to its simplified interpretation, even if a person is totally blind or keeps eyes closed at all times, but is active at night and sleeps during daytime, his or her circadian gene clock function, formed during the millions of years of evolution, may be disrupted. This would stress the immune function and thus increase the susceptibility of such a person to various diseases, including BC&PC. **If this hypothesis is correct, then any person, who regularly works, drive a car, ride a bus or regularly attends places of entertainment late at night and sleeps during daytime, is at high risk of developing BC&PC,** no matter whether such a person is directly exposed to high intensity LAN or not." [Bold emphasis added.]

5.2.15 The authors make the following recommendations:

- "…we should thus try to adhere to the ''traditional'' 12L:12D [12 hours light and 12 hours dark] cycle, by avoiding, whenever possible, nighttime activities, including TV watching and computer gaming, especially for children. Considering that not too many of us have to work nightshifts, for the majority of us, giving preference to late night activities over daytime ones becomes the matter of choice, and we should be aware of potential consequences."
- "Second, when we rest, bright lights in our bedrooms should be avoided, both lights coming from indoor and outdoor light sources. Low intensity (yellow and red non-LED) lights may, in most cases, satisfy our needs in the nighttime illumination, mainly for the elderly, to find their way to the bathroom at night, and for children, to feel secured. Preventing LAN penetration from outdoor sources (such as e.g., street lights, illumination of public buildings, and lights from moving vehicles) may also be relatively easy in most temperate climates, in which constant cross ventilation of indoor spaces by keeping windows open at night is not as necessary as in tropical climates. Even if we want to keep windows open during nighttime, the penetration of outdoor LAN can be reduced by closing curtains and shades."
- "Third, local authorities may contribute to the reduction of light pollution by implementing more sustainable nighttime illumination policies, such as, lowering illumination intensities in public places to minimally acceptable levels, by surveying actual needs and caring to provide minimal light levels required by certain activities (e.g., walking, driving, etc.) without over-illumination. In addition to health benefits, additional energy savings from such policy can naturally be expected."
- "As electricity becomes more accessible, more places are illuminated, especially (but not only) in urban areas. Nighttime illumination is commonly used for advertising and illuminating buildings, such as art monuments and public buildings being cultural landmarks all over the world. This source of light pollution, cannot, in our view, be avoided completely. However, it can (and should) be restricted to certain hours in the early dark period, using long wavelength illumination which has a minimal effect on reducing pineal MLT production, where after which the illumination should be switched off."
- "As we developed devices for tracking air pollutions, devices for tracking light pollution should also be developed, and light intensity above a certain threshold should be dimmed. Such LAN-tracking devices should be able to distinguish between different wavelengths thus helping to avoid an extensive use of short wavelength illumination. In addition, **street lights should not be directed at homes but rather be focused on pavements and road surfaces, in order to decrease light pollution in sleeping habitats**." [Bold emphasis added.]

- "Regulations on nighttime advertising (which is virtually non-existent today) should also be implemented and switching off such illumination can contribute to the most important aims of decreasing light pollution and energy-saving. Unfortunately, we are used to the fact that huge areas are lit at night without any actual need. This attitude should change and the light needs to be pointed at the objects it is meant to illuminate. For example, lampposts of 15m above the road surface become a strong source of light pollution due to higher light intensity such lampposts emit."
- "Public policy makers should also be convinced to curb the wide scale introduction of short wave length illumination, which is potentially the most dangerous component of light pollution."
- "Education of consumers may also play a role, helping them to make informed choices. As we mark today alcohol and tobacco products, which have negative effects on our health that we are well aware of, we should also consider marking packages of short wavelength light bulbs with a consumer warning, such as, for instance: ''This bulb emits light of short wavelength of less than 530 nm, and such illumination effectively suppresses pineal MLT production, when used at nighttime, and may thus endanger your health.'' After reading this warning we can decide whether we want to buy this product or not. Although such a consumer warning may sound ''overreacting'' at this point of time, it may eventually come into practice, as the authors of this book believe, as research develops and new evidence about light pollution as a source of toxicity and its adverse health effects becomes available to the public."
- "MLT treatment and avoidance of exposure to short wave length illumination by using appropriate illumination can be used as means for prevention. However, these ideas should be transferred to medical protocols after wide scale surveys and experiments."
- "Blue wavelength blocker glasses that help to avoid MLT suppression may also be a reasonable solution for home use and for shift workers who have sleep breaks during their night shifts. Of course, it is better to focus on sustainable illumination than to produce unsustainable illumination and then look for ways to overcome it. However, such glasses and other gadgets can be a temporary solution until more sustainable illumination are implemented, just like swallowing MLT pills before going to sleep at night."
- "…on/off switches should be replaced by dimmers, which can increase light intensity gradually, in the way it happens under natural conditions, for instance, during sunrise, and darken the room, like at the sunset when we are indoors. By not moving to the abrupt darkness at once, we can adjust our vision system to the changing illumination."

- "LED illumination (for instance, stand-by and control lights in various devises and equipment) is considered to be most energy saving. However, its introduction into our homes in so many forms should worry us the most. Although each one of them maybe of low intensity but when they are lit together, they may suppress nighttime MLT production. These devices should therefore be removed from our sleeping habitat and kept in a separate room. This is a simple solution that can reduce our exposure to LAN."

5.3 Primary research studies published since the latest research reviews

A WORKING THRESHOLD FOR ACUTE NOCTURNAL MELATONIN SUPPRESSION FROM "WHITE" LIGHT SOURCES USED IN ARCHITECTURAL APPLICATIONS. (2013). REA MS AND FIGUEIRO MG. JOURNAL OF CARCINOGENESIS & MUTAGENESIS.

5.3.1 This study was an experimental study that undertook two studies with 14 participants each. In Study Group 1 there were seven male and seven female participants. In Study Group 2 there were 1 male and thirteen female participants.

5.3.2 Participants were exposed to four white light LED sources on a set of safety goggles for one hour. There were two LEDs for each lens with filtering of blue light below the safety threshold of 100W/(m2 sr) and glare reduction through the use of diffusion tape. The light had a correlated colour temperature (CCT) of 2670 +/- 29 K. The target illuminance levels for Study 1 were 8, 22 and 60lux. The target for Study 2 was 60, 200 and 720 lux.

5.3.3 The study found that melatonin was suppressed at 200 and 720 lux.

5.3.4 However, melatonin suppression after exposure to 60 lux was observed in Study Group 1 but not in Study Group 2. However, in both cases, the 95% confidence intervals (CIs) encompassed zero, i.e. no significant effect or difference for exposure to 60 lux was observed.

5.3.5 The 95% confidence intervals for melatonin suppression also encompassed zero for both 8 and 22 lux i.e. no significant effect or difference for exposure to 60 lux was observed.

5.3.6 In the discussion section the authors say the following: "Depending then upon one's own perspective with regard to misses or false positives, these measured levels of evening light may or may not be considered a health risk. A great deal more data will have to be collected and analyzed (considering both false positives and misses) to establish a more precise threshold light exposure for nocturnal melatonin suppression. Nevertheless, in

the public interest, it seems incumbent upon the scientific community to establish a *hypothesized working threshold* for light exposure at night until much more data are collected and analyzed."

5.3.7 "Here we propose, for further testing, that the hypothesized working threshold for acute nocturnal melatonin suppression be 30-minute exposure to a 30 lux at the cornea from "white" light sources that might be used in architectural applications."

5.3.8 The authors then state that though their study found that 60 lux did not reliably suppress melatonin; given the consistency between their study findings and their model prediction, concern for health risk and their field measurements of actual exposure in the home they believe that a one-hour exposure to 60 lux of white light is too high as a working threshold for light induced melatonin suppression at night.

5.3.9 The authors then end by with following statement: "An important consideration for understanding the increased incidence of breast cancer is the **disruption of regular circadian rhythms associated with living in a modern society**. Disruption to the circadian cycle, **either by melatonin depletion or by irregular light/ dark cycles**, has been shown to increase tumor growth and mortality in animal models [42-46]. Therefore, further investigating the threshold for acute melatonin suppression and disruption of circadian rhythms is an **important first step towards better understanding the effects of LAN on diseases**. [Bold emphasis added].

<u>THE POTENTIAL OF OUTDOOR LIGHTING FOR STIMULATING THE HUMAN CIRCADIAN SYSTEM. (2012). REA MS, SMITH A, BIERMAN A AND FIGUEIRO MG. ALLIANCE FOR SOLID-STATE ILLUMINATION SYSTEMS AND TECHNOLOGIES (ASSIST)</u>

5.3.10 This study provides a quantitative analysis of the impact of light at night, particularly from streetlights of different spectral power distributions, on the human circadian system. A model of human circadian phototransduction was used to estimate levels of circadian stimulation, as measured by melatonin suppression by light, from four typical outdoor light sources as might be experienced by people under different realistic scenarios.

5.3.11 The modelling scenarios used was of a 20 year old person viewing for one hour four different light sources at eye height (1.5m from the ground) with the street light (luminaire) mounted at 8.2m (27 feet) from the ground at three distances.

5.3.12 The four light sources were: High Pressure Sodium (HPS, CCT 2050K), Metal halide (MH, CCT 4000K, Cool White LED 1 (CCT 5200K) and Cool White LED 2 (CCT 6900K).

5.3.13 The three distance scenarios were:

- Reference condition: The person directly views each luminaire from a point 5ft (1.5m) from the vertical centre line of the mounting pole, and the illuminance at the cornea is 95 lux.
- Scenario 1: This same person is now looking down the road and is 10ft (3m) away from the vertical centre line of the mounting pole at the location where the luminaire would produce the maximum illuminance, 27 lux, at the cornea.
- Scenario 2: This same person is 30ft (10m) away from the vertical centre line of the pole looking directly at the luminaire; the illuminance at the cornea is 18 lux.

5.3.14 Under the two more realistic scenarios, based upon the model calculations, the 20 year old would not have reliably suppressed nocturnal melatonin (above the 10% uncertainty level for assaying melatonin) after one hour of exposure to the warmer 5200K "cool white" LED, the MH or the HPS sources. For both practical scenarios, some melatonin is expected to be suppressed for the cooler 6900K "cool white" LED source: 12% for scenario 1 and 15% for Scenario 2.

5.3.15 The authors' concluding statement and emphasised in their abstract (summary) is that the 6900K cool-white light LED has a small/modest stimulating effect on the human circadian system after one hour exposure corresponding to a 12-15% nocturnal melatonin suppression.

5.3.16 For older people and exposures less than one hour there is likely to less melatonin suppression.

5.3.17 Key uncertainties that the authors' mention, apart from the uncertainty in the relationship between melatonin suppression and human health effects, are:

- Individuals with inherently high concentrations of melatonin may be less susceptible to diseases, such as cancer, than those with inherently low concentrations, regardless of the impact of light at night on circulating melatonin.
- A person's light history also affects the degree to which light can suppress melatonin. A person working outdoors during the day will have a higher threshold to light induced nocturnal melatonin suppression than those who spend the day in

dimly illuminated interiors. So a fixed level of light may have differential consequences on people with different lifestyles.

- There is great uncertainty in the threshold response to light at night.
- Whether a small but constant suprathreshold amount of suppression has a cumulative effect on human health is also unknown.

BREAST CANCER AND CIRCADIAN RHYTHM DISRUPTION FROM ELECTRIC LIGHTING IN THE MODERN WORLD. (2014). STEVENS RG, BRAINARD GC, BLASK DE, LOCKLEY SW AND MOTTA ME. CA A CANCER JOURNAL FOR CLINICIANS.

5.3.18 "…under carefully controlled conditions, retinal exposure to illuminances of as low as 1 lux or less of monochromatic light at wave- length 440 to 460 (blue-appearing light) can significantly lower nocturnal melatonin, as can <100 lux of broad- spectrum fluorescent light. These same light levels can also elicit significant phase shifts of the circadian clock and directly enhance alertness; approximately 100 lux exposure will cause about 50% of the maximum response. Such light exposure, when experienced in the evening at home from bedside lamps, TVs, computer screens, tablets, and other devices, causes suppression of melatonin, delays the timing of circadian rhythms, and elevates alertness, all of which make it harder to fall asleep, make it harder to wake up in the morning, and restrict sleep."

5.3.19 "It is now evident that, among other things, 1) bright light exposure at night suppresses melatonin in all sighted persons; 2) shorter wavelength (blue) light is most effective and longer wavelength (red) is least effective in melatonin suppression, alerting the brain, and resetting the circadian pacemaker; 3) there is a dose response in which, the greater intensity of the light, the greater percentage suppression of melatonin; 4) there are differences in individual sensitivities to light-induced melatonin suppression; and 5) characteristics of daytime lighting can alter sensitivity to light exposure during the night.

5.3.20 "Inadequate or interrupted sleep has short-term safety consequences through increased sleepiness and potential longer term risks to chronic diseases, including cardiovascular disease, diabetes, and some cancers. Sleep is essential to health; however, it is not sufficient to synchronize the circadian clock: a strong daily cycle of light and dark is required…"

5.3.21 "The normal nocturnal rise in circulating melatonin is not affected by being asleep or awake but is severely attenuated by light exposure during the night."

5.3.22 "Because dark and sleep are difficult to adequately disentangle in studies of diurnal animals such as humans, it is not clear whether the proximate cause of metabolic changes is sleep disruption itself, disruption of circadian physiology, and/or a direct effect of light exposure."

5.3.23 "It is not yet clear which type of disruption, circadian or sleep, has the greater effect, or how they interact. Future research should attempt to distinguish the relative roles of circadian disruption, sleep disruption, melatonin suppression, or light itself on the interaction between electric lighting and adverse health effects, as these distinctions are vital to guide intervention strategies."

5.3.24 "Investigation of light effects on mammary tumorigenesis in rodents began in the 1960s. For both chemically induced and spontaneous tumors, most of these studies showed an increase in tumor incidence and number by exposure to a constantly lighted environment compared with a 24-hour alternating schedule of light and dark (eg, 24 hours of light vs 12 hours of light:12 hours of dark)."

5.3.25 "Beginning in the 1980s, researchers focused more closely on the ability of melatonin to inhibit mammary carcinogenesis and on the impact of a constant light environment in animal rooms on mammary tissue development, and major effects were reported… At the time of these studies, light was used as a tool for melatonin suppression and, itself, was not considered as a human exposure of consequence. It is important to note that constant exposure to bright light not only sup- pressed melatonin synthesis in these experiments but also induced additional detrimental effects on the circadian activity of the SCN in general."

5.3.26 "In the early 2000s Blask and colleagues began to examine the effect of various levels of light during the night on the growth of a human breast cancer xenograft in nude rats. They predicted that nighttime light exposure would suppress melatonin and that this suppression would significantly increase an existing tumor's ability to utilize linoleic acid for its growth…. Blask et al found a dose-dependent suppression by nighttime fluorescent light exposure on blood melatonin levels in exposed rats, a significant

increase in metabolism of linoleic acid in the human breast cancer xenografts, as well as a large increase in tumor growth rate… even at the lowest illumination level, there was a partial suppression of melatonin and a corresponding increase in tumor growth rate… Blask et al took this experimental design an important step further by perfusing the human xenografts growing in the nude rat with human blood taken from young women under three conditions: 1) during the day, 2) at night during the dark, and 3) at night after light exposure to the subject. Blood taken at night in the dark and, thus, high in melatonin, strongly inhibited the growth and metabolism of the xenografts; whereas blood taken at night from the same young women after light exposure and, thus, low in melatonin, did not slow the tumor growth at all."

5.3.27 "…exposure to light at night early in life (even in utero from exposure of the pregnant mother) may affect breast cancer risk throughout life."

5.3.28 "The strongest evidence to date [on light at night and breast cancer risk] are data showing that women who work nights (shift work) are at higher risk of breast cancer. These data led the International Agency for Research on Cancer (IARC) to conclude that "shift work that includes circadian disruption is probably carcinogenic to humans (Group 2A)." The American Medical Association then broadened the topic in a policy statement in 2012 on the health hazards of light at night in general. Since the IARC classification, there have been more epidemiological studies in various settings and populations that have supported an association…"

5.3.29 "Shift work has been used as a surrogate for exposure to light at night and circadian disruption in the epidemiological studies of cancer. (This circadian disruption can include melatonin suppression, clock gene disruption, and sleep disruption; the epidemiological studies to date cannot distinguish among these three.)"

5.3.30 "Almost all persons in the modern world use electric lights in the evening and at night. **The degree of melatonin suppression is a continuum, with shift workers likely to be the most suppressed and blind people the least (on average), but each and every day, people suppress their melatonin to some degree if they are not in the dark at dusk and stay there until dawn**. Similarly, all people in the modern world experience some degree of circadian or sleep disruption because of electric light, and, again, the degree of disruption is distributed continually. The electric light exposures typically seen

in the evening at home have strong effects on suppressing melatonin, shortening sleep, and disrupting circadian rhythmicity." [Bold emphasis added]

5.3.31 "An important direction for future research includes developing novel animal models and experimental strategies that can determine the relative contributions to breast cancer risk of circadian phase shifts, sleep deprivation, and nocturnal melatonin suppression within the spectrum of circadian disruption induced by light exposure at night."

EVALUATING POTENTIAL SPECTRAL IMPACTS OF VARIOUS ARTIFICIAL LIGHTS ON MELATONIN SUPPRESSION, PHOTOSYNTHESIS, AND STAR VISIBILITY. (2013). AUBE M, ROBE J AND KOCIFAJ M. PLOS ONE.

5.3.32 This study described three indices developed by the authors to better estimate the level of human melatonin suppression (Melatonin Suppression Index), inappropriate stimulation of photosynthesis in plants (Induced Photosynthesis Index) and light pollution into the sky (Star Light Index) for any given artificial light source. They state that this is a better way than Correlated Colour Temperature (CCT) and Colour Rendition/Rendering Index (CRI) that are those currently being used by the lighting industry. Using their approach they tested 13 types of outdoor lamps using the MSI produced by High Sodium Pressure lamps as their reference baseline (MSI 0.12, with midday sunlight in western/Northern Europe having a CCT of 6500K and an MSI of 1). They found that only Low Pressure Sodium, 2700K blue-light filtered LED lamps and similar lamps had lower MSI values (0.02 and 0.08). Incandescent, LED 2700K, halogen, LED 5000K and metal halide lamps had values of 0.26, 0.29, 0.38, 0.54 and 0.62. How and why the13 lamps assessed in the study were chosen is not discussed nor why the High Pressure Sodium lamp was judged to be the baseline and not for example the low pressure sodium lamp.

LIMITING THE IMPACT OF LIGHT POLLUTION ON HUMAN HEALTH, ENVIRONMENT AND STELLAR VISIBILITY. (2014). FALCHI F, CINZANO P, ELVIDGE CD, KEITH DM, HAIM A. JOURNAL OF ENVIRONMENTAL MANAGEMENT.

5.3.33 "…to date there are no doubts that exposure to light at night (LAN) decreases pineal melatonin (MLT) production and secretion and are not only a source for phase shift in daily rhythms. Apart of timing and exposure duration, the two light variables responsible

for the suppression of MLT production are: 1) light intensity and 2) wavelength. Therefore, it seems that the combination of both variables should be considered for the threshold of LAN. Light intensity levels found to suppress MLT production are decreasing as research progresses. During the eighties of last century, it was shown that bright light at an order of thousands of lux was requested for abolishing the secretion. The discovery of a novel photoreceptor, the Non Image Forming Photoreceptors (NIFPs), and the photopigment melanopsin gave an opportunity for a better understanding of light perception by humans and showed the effects of spectrum in the human high response to LAN, in which the impact of wavelength on humans was assessed by measuring melatonin, alertness, thermoregulation and heart rate draw the attention to the significant role of wavelength. It was shown that exposure of 2h to mono-chromatic light at 460 nm in the late evening significantly suppressed melatonin secretion while under the same intensity, exposure timing and duration but at wavelength of 550 nm such effects were not observed. Already Wright et al. showed that even illuminance as low as 1.5 lux affects circadian rhythms. Moreover, recently it as shown that bedroom illumination, typical of most homes in the evening, is sufficient to reduce and delay MLT production. From the results of these studies it can be noted that MLT suppression by LAN is wavelength depended and intensities can be much lower than those used several decades ago."

5.3.34 "Alteration of the circadian clock may cause performance, alertness, sleep and metabolic disorders. Exposure to light at night suppresses the production of the pineal hormone melatonin, and since melatonin is an oncostatic or anti-carcinognenic agent, lower levels in blood may encourage the growth of some type of cancers. MLT seems to have an influence on coronary heart disease. LAN acts directly on physiology, or indirectly by causing sleep disorders and deprivation, that may have negative effects on several disorders such as diabetes, obesity and others."

5.3.35 "Therefore, the increase in light intensity on the one hand and the wide use of "environmentally friendly bulbs" with a short wavelength emission on the other, are probably having severe negative impact on health through the suppression of MLT production."

5.3.36 "In the natural environment, animals and plants are exposed to light at night levels that vary from about 0.00005 lux of the overcast sky, to 0.0001 lux by the starry sky on a moonless night, to 0.02 lux at the quarter moon, to 0.1–0.3 lux during the week around full moon. The artificial light of a typical shopping mall, 10-20 lux, is up to 200 thousand times brighter than the illuminance experienced in the natural environment around new moon."

5.3.37 "This strong evidence of the adverse effects of artificial light at night on animals and on human health should be balanced against the supposed positive effects on safety and security."

5.3.38 "…an effective law to control light pollution should implement this set of rules:

- do not allow luminaires to send any light directly at and above the horizontal;
- do not waste downward light flux outside the area to be lit;
- avoid over lighting;
- shut off lights when the area is not in use;
- aim for zero growth of the total installed flux;
- strongly limit the short wavelength 'blue' light."

STUDIES ON THE BENEFICIAL EFFECTS OF BLUE LED LIGHTING.

5.3.39 Two study teams have looked at the beneficial impacts of blue light and while these studies have similar weaknesses to the studies described in this Chapter they demonstrate that the issues around blue light are not clear cut and that some studies and some countries are purposely exposing people to blue light for its beneficial effects. The two sets of studies are described briefly below:

- Two papers examined the effects of blue light and caffeine on cognitive function, alertness and overall mood. They found that participants exposed to 470nm blue light of 40 lux for 1 hour had positive effects on all the above.[2] [3]

[2] Beaven, C. M., & Ekström, J. (2013). A comparison of blue light and caffeine effects on cognitive function and alertness in humans. *PloS One*, *8*(10), e76707. doi:10.1371/journal.pone.0076707

[3] Ekström, J. G., & Beaven, C. M. (2014). Effects of blue light and caffeine on mood, 3677–3683. doi:10.1007/s00213-014-3503-8

- Three papers examined the use of blue lights on parts of some railway platforms in Japan between 2008-2010 as an intervention to reduce the number of suicides of people jumping in front of trains. The studies found that there may be some reduction in suicides that could be attributable to this intervention.[4] [5] [6]

5.3.40 While trying to identify what type of blue light was being used by Japanese railway companies mentioned above the review team identified that Network Rail is/has been trialling the use of blue LED lighting on some railway platforms (Romford Station and Gatwick Airport Station) in England to prevent suicides and crime and anti-social behaviour based on the experience of Japan's railways.[7] [8] [9] [10] It is unclear what kind of blue LED light is being used in these trials in the UK and it was beyond the scope of this Review Report to investigate this further.

5.4 Research studies and survey of LED street lighting pilots and programmes

5.4.1 One publically available survey report analyses the views and attitudes of communities to the piloting and implementing LED street lighting projects.

BLOXWICH LIGHTING PFI RESIDENTS' SURVEY SPRING AND AUTUMN 2012 SUMMARY OF FINDINGS, JANUARY 2013, WALLSALL COUNCIL [Emphasis in bold emphasis is from the report]

5.4.2 Two resident questionnaires, one before (Spring Survey) and one after the installation of new LED street lighting in the area (Autumn Survey) were undertaken in Bloxwich where

[4] Matsubayashi, T., Sawada, Y., & Ueda, M. (2013). Does the installation of blue lights on train platforms prevent suicide? A before-and-after observational study from Japan. *Journal of Affective Disorders*, *147*, 385–388.

[5] Matsubayashi, T., Sawada, Y., & Ueda, M. (2014). Does the installation of blue Lights on train platforms shift suicide to another station?: Evidence from Japan. *Journal of Affective Disorders*, *169*, 57–60.

[6] Ichikawa, M., Inada, H., Kumeji, M. (2014). Reconsidering the effects of blue-light installation for prevention of railway suicides. *Journal of Affective Disorders. 152–154, 183–185.*

[7] Romford blue lights project. (2014). Community Safety Resource Centre. http://www.railcommunitysafety.com/News/Pages/Romford-blue-lights-project.aspx

[8] Can blue light make Britain's railways safer?. (2014). Lux Review. https://www.luxreview.com/news/478/can-blue-light-make-britain-s-railways-safer

[9] Soothing blue platform lights will be trialled in railway stations to tackle the rise in suicides on the tracks. (2014). Awford J. Mail Online. http://www.dailymail.co.uk/news/article-2799053/soothing-blue-platform-lights-trialled-railway-stations-tackle-rise-suicides-tracks.html

[10] Calming blue platform lights may stop rise in rail suicides. (2014). Hookham M. The Sunday Times. (Paywall). http://www.thesundaytimes.co.uk/sto/news/article1472950.ece

590 sodium orange lanterns were replaced with LED lanterns. There was no description of what type of LED lighting was piloted.

5.4.3 The Spring survey received 477 responses, a response rate of 23%, whilst the Autumn survey received 591 responses, a 29% response rate.

5.4.4 The following is the summary of the findings as presented in the report:

5.4.5 During the day and during the hours of darkness, **respondents predominantly travel in the local area by car**, with around three fifths of respondents usually travelling this way.

5.4.6 Most respondents travel after dark at least a weekly or more often than this. **Travel after dark on foot is less frequent** with some respondents never travelling by road or on foot after dark.

5.4.7 In both the Spring and Autumn surveys compared to other aspects **lighting the roads and pavements during the hours of darkness was seen as most important to respondents**, with the lighting of pavements being slightly more important than roads. Energy efficient lighting and reducing energy bills are also important aspects.

5.4.8 Although still important, compared to the other aspects, lighting the roads and pavements during the small hours (12am to 5am) is of lower importance.

5.4.9 The attractiveness of lanterns is least important.

5.4.10 The vast majority of respondents feel that the **new LED lighting levels are about right** (68%), slightly less than in the Spring survey (72%). But a slightly higher proportion now think that the lighting is too dim (28% compared to 25%). Just 3% feel that the new lights are too bright.

5.4.11 Some respondents comment that the lights shine too brightly into their homes, keeping them awake at night. Others comment that the lights cast more areas of darkness and shadows, creating a reduced sense of security.

5.4.12 Compared to the Spring survey, following the installation of the LED lighting, more respondents now say that visibility on the footway (19% to 37%) and on the roads is very good (19% to 32%). However **a notable increase is seen in the proportion who feel that visibility from their front door / window is now very poor** (6% to 15%).

5.4.13 Since the installation of the new lighting, more than double the proportion of respondents now say that lighting coverage at ground level is very good (29%) and more than four times the proportion say the colour of the lighting is very good (36%). Colour definition of the new lighting is now also more highly rated, although a notable proportion feel it is poor (24%).

5.4.14 Compared to the old lighting **more respondents now feel that visibility overall is very good** (31%), however many respondents feel it is poor (17%) or very poor (10%).

5.4.15 The greatest improvement of the new lighting has been the colour, three fifths of respondents say the colour is better.

5.4.16 Around half of all respondents feel that the colour definition, lighting coverage at ground level and visibility overall is better. However **between a quarter and around a third feel these aspects are worse.**

5.4.17 Whilst some people say the new lighting makes them feel safer, overall the new lights appear to have **a limited impact on feeling safer**, with an increase in the proportion who strongly disagree that the new lighting makes them feel safer on foot (5% to 16%) and when using the road (4% to 14%). It must be noted that several factors contribute to feeling safe and respondents were not asked how safe they actually feel.

5.4.18 Overall, taking everything into account;

- over half of all respondents feel the new lighting is better (55%)
- 13% feel it is the same
- 31% feel it is worse

5.4.19 The main reasons for saying the new lighting is better include it being brighter and clearer, being a better more natural colour and providing better ground coverage.

5.4.20 The main reasons for saying the new lighting is worse include a reduction in coverage, reduced visibility with some areas now in darkness (between columns and up to properties) which some believe poses a safety and security risk.

5.5 Past HIAs on LED street lighting

5.5.1 The review did not identify any other HIAs in the public domain on LED street lighting programmes since the publication of the 2013 HIA Report.

5.6 Conclusion

5.6.1 The evidence review findings of this follow up review are in line with the evidence review findings of the 2013 HIA Report.

5.6.2 **This review has found no evidence that LED street lighting, including 'cool' white and blue-rich white LED street lighting, has any additional health and wellbeing effects beyond that found for artificial lighting in indoor or outdoor settings in general.**

5.6.3 **Most importantly while 'cool' white light and blue-rich white light are discussed in the literature there is no clear consensus on what this means in terms of Correlated Colour Temperature (CCT) measured in Kelvins (K). Hence there is no consensus on what level of lighting in terms of Correlated Colour Temperature (CCT) is optimal.**

5.6.4 There is little new research since June 2013. There is still no specific research literature on the health effects of LED street lighting. There is also no specific research on the health effects of mixing of LED and high or low pressure sodium lighting.

5.6.5 The majority of reviews and research articles reviewed in this report are cautious in making wide ranging recommendations (and where they do they apply to the whole range of artificial lighting that people are exposed to - indoors and outdoors - and all call for more research in this area. This is because the current evidence is weak and mostly associated with animal, in vitro and ecological/cross-sectional studies (where accurate levels of exposure and cause and effect relationships are difficult to identify).

5.6.6 The research reviews identified in this evidence review all agree that artificial lighting, and probably blue-rich white light, whether from LED or other sources, can have some negative health and wellbeing impacts depending on the intensity, duration, pattern and characteristics of the light exposure alongside levels and types of exposure in the hours beforehand. This includes indoor lighting, light emitting devices such as computers as well as outdoor lighting.

5.6.7 Importantly, the effect of artificial lighting is nuanced, subtle and complex and there is some evidence that people respond differently to the same lighting conditions, e.g. ethnicity, gender, socio-economic status, and can adapt to different lighting conditions and that this can reduce the effects of artificial lighting.

5.6.8 Some people with certain existing health conditions that are affected by light, and possibly children, may be more sensitive to artificial lighting.

5.6.9 There is some discussion in the literature of regulatory issues in terms of whether existing regulatory guidance on assessing the light emitted by artificial lighting systems is able to adequately categorise the likely light exposure from LED lighting systems.

5.6.10 The main difference between LED lighting and other forms of artificial lighting is that it can produce light that is more in the blue part of the light spectrum, i.e. producing a more whiter bluer light than incandescent, fluorescent or outdoor sodium or metal halide lighting which can be much yellower and can be more intense (given the size and shape of LEDs and the way the lighting system is constructed with reflectors and lenses to focus the light). Exposure to light in the blue part of the spectrum particularly single blue colour (monochromatic blue) light can have a potentially greater effect on the melatonin suppression/circadian rhythm. The exact contribution between artificial light and blue-rich white light from street lighting compared to indoor, computer equipment and other outdoor sources has, as far as this review has been able to ascertain, not been researched or modelled.

5.6.11 There is some weak evidence that blue light can have beneficial effects in terms of alertness and cognitive function and suicide prevention. What is interesting about these reports is that in these experimental and real world contexts research participants on the one hand and railway passengers on the other have been exposed to blue light with no reported ill effects.

6 Health Impacts of the Trafford LED Street Lighting

6.1 Introduction

6.1.1 This chapter presents the findings of the review, and where appropriate an update or amendment, of the analysis and conclusions of the 2013 HIA Report in light of the evidence reviewed in Chapter 4.

6.2 Health impacts of LED street lighting

6.2.1 The key conclusions of this review, which are the same as those of the 2013 HIA Report, are that:

- Any proposed introduction of LED street lighting in Trafford, and ad hoc replacement of existing lighting has, overall, no (neutral) or a minor positive health and wellbeing impact for the residents, workers and visitors of Trafford compared to the existing non-LED type of street lighting being used.
- The health impact of white LED street lighting, including 'cool' or blue-rich at 5700K, is likely to be similar to that of existing non-LED lighting because the contribution of the exposure of residents to LED street lighting will be a small proportion of their overall exposure to artificial lighting indoors and other types of lighting outdoors.

6.2.2 Though there is some research that shows a relationship between exposure to artificial lighting, and blue-rich white lighting, and possible physical and mental health and wellbeing effects, the research evidence is weak. Furthermore, such effects would not be likely to arise even as a result of a LED street lighting replacement programme because of the type and intensity of the light likely to be emitted and the low duration and intermittent pattern of exposure that almost all Trafford residents, workers and visitors are likely to have to LED street lighting.

6.2.3 Trafford Council's Street Lighting Maintenance Policy was reviewed in light of the scientific evidence and the references to LED street lighting are judged to be in line with the evidence and unlikely to cause adverse health impacts.

6.3 Health impacts of mixed LED and sodium lighting

6.3.1 There is no research evidence on this issue.

6.3.2 Overall, though there is likely to be a difference in the quality/characteristics of light generated between the LED and sodium lighting, the health impact of mixed LED and sodium lanterns is likely to be similar to that for sodium lighting on its own.

6.4 Reasons for why the conclusions remains the same as the 2013 HIA Report

6.4.1 There is a lack of evidence on the health effects of LED street lighting and blue-rich white street lighting. Most discussions are based on an extrapolation of research on artificial light at night in general and experimental or animal studies on the effects of blue-rich white light or specific parts of the causal pathway between light exposure at night and health effects e.g. suppression of melatonin.

6.4.2 Though this was not explicitly stated in the 2013 HIA Report it was the underlying public health consensus that informed the analysis undertaken in that report. The causes of most disease, particularly complex disorder such as cancer, cardiovascular disease, obesity, diabetes and, probably, eye disorders identified in the literature are multi-factorial i.e. no single cause is enough. More importantly social and individual factors such as socio-economic status (e.g. being on a low income, insecure job), the neighbourhood we live in (e.g. deprived, lack of greenspace, high levels of crime and/or anti-social behaviour) and the social support networks we have as well as diet, lifestyle, age, gender and ethnicity all play an important and large part in causing the above diseases.

6.4.3 Compared to the contribution of the above risk factors and the greater exposure of most people to indoor and other sources of outdoor light, taking account of the current state of the evidence, a potential contribution of LED street lighting, even up to 5,700K, even if considered as a potential risk factor for the above diseases, is likely to be significantly lower.

7 Mitigation and Enhancement Measures

7.1 Introduction

7.1.1 This chapter presents the mitigation and enhancement measures of the 2013 HIA Report and where appropriate these have been amended in light of the evidence reviewed in Chapter 4.

7.2 Procurement of the LED lighting systems and its management

7.2.1 The measures in this section of the 2013 HIA Report continue to be applicable.

7.2.2 Consider whether, within the limits of commercial viability, some future-proofing should be written into the procurement contract, such that during the life of the LED lighting systems and its management there is scope for both operational and failed LED lights to be replaced with ones that better meet the changing requirements of local residents needs and the local authority so that environmental and health and safety benefits, within existing/future financial and economic constraints, are maximised over the life of the LED lighting.

7.2.3 Consider having contingency technologies or other appropriate measures written into the procurement contract to minimise any potential glare from any new lighting system coming into local residents' homes.

7.2.4 Check with other councils, particularly those in the Greater Manchester area, to ensure that the best LED lighting system is procured from a combined environmental, health and economic standpoint.

7.3 Design aspects of the LED lighting and technology

7.3.1 No recommendations on the specific design, types or levels of street lighting would be appropriate given the lack of evidence that LED street lighting has any adverse health impacts. The review has found that there continues to be conflicting conclusions in the research literature and no emerging consensus on the adverse effects of artificial lighting, including LED and blue rich white lighting. There is also no emerging consensus on the acceptable types and levels of artificial and LED lighting.

7.4 Construction phase

7.4.1 The measures in this section of the 2013 HIA Report continue to be applicable but have been amended to make the points clearer.

7.4.2 Aim to make the LED lighting system poles in keeping, with the wider architectural environment and streetscape in residential areas.

7.4.3 Aim to use existing street light locations on streets and heights of lighting fixtures; and avoid changing the spacing between street lights or moving the location nearer to the boundary of householders properties.

7.4.4 Ensure that any construction or setting up of the LED lighting is communicated beforehand and undertaken in a manner that reduces any potential disruption to local residents both in terms of access and, more importantly, night-time illumination. For example, in line with existing council procedures, consider the following:

7.4.4.1 Develop a communication plan, and use as appropriate, door-to-door leaflets, residents' associations, and other communication channels to ensure local residents are aware of the construction/setting up and where they can complain and get issues remedied. Ensure that materials are translated into community languages where appropriate (e.g. Urdu for Pakistani communities). Work with community development team to target these materials at relevant communities.

7.4.4.2 Develop a construction/setting up management plan ensuring that sub-contractors are appropriately briefed about what they are doing and why this is being done as well as be briefed on how to ensure that they minimise any disruption to local residents and what to do and who to contact if there is likely to be unanticipated disruption e.g. that street lights could not be switched on, etc. so that the local authority can take remedial action and inform local people about why the street lights are not on or access is disrupted.

7.4.4.3 Have a clear and communicated complaints and grievance procedure with a telephone number email address and postal address as well as a designated

person within the council who will take responsibility and has the authority and power to deal with and resolve local residents' complaints and concerns in a timely manner (e.g. within the council and as appropriate, to key local organisational stakeholders and local residents through a variety of media or in appropriate languages for the local population). A designated council member of staff is important even if the lighting is the responsibility of a private sector third party.

7.4.4.4 Where whole street or area lighting is being considered, ensure a consistent and logical approach to how areas are converted to LED street lighting and ensure that locally coherent neighbourhoods have similar lighting i.e. that areas are done once and then not returned to unless there is a technical problem or a residents' complaint.

7.4.4.5 Ensure that the light poles and LED fixtures are installed according to current health and safety standards for lighting; by professional lighting engineers or technicians supervised by lighting engineers; and by a lighting company that has a track record in doing this or similar kinds of work and low numbers of residents' complaints in their previous projects.

7.4.4.6 Ensure the implementation phase is linked with the Council Tree Maintenance department to both preserve trees on the streets should extra digging on pathways be required but also to ensure that trees and tall shrubs are not reducing illumination or causing unintended lighting effects.

7.5 Operation phase

7.5.1 The measures in this section of the 2013 HIA Report continue to be applicable.

7.5.2 Ensure that there is a clear and communicated set of procedures and processes in place within the council to deal with glare into local residents' homes from the new lighting system.

7.5.3 Where dimming is considered ensure that:

7.5.3.1 Develop a set of criteria that determines which locations are not dimmed in consultation with local residents and key public and private stakeholders such as emergency services and local businesses.

7.5.3.2 There is initial and on going, regular two-way dialogue and discussion between residents, residents groups and the council.

7.5.3.3 Monitor key crime, safety and road traffic incident statistics.

7.5.3.4 Consider switching the lights back to normal brightness if there are significant complaints from local residents and alternative options are not able to address residents' complaints.

7.5.3.5 Below is a list of potential locations where street lights could generally remain on at night, based on the approach taken by other local authorities:

- Main traffic routes (dimming of street lights may be introduced if appropriate)
- Locations with above average road traffic night time injury accident record
- Areas provided with CCTV local authority/police surveillance equipment
- Areas with 24hr operational emergency services sites including hospitals
- Pedestrian crossings and subways
- Where there are potential hazards on the Highway (roundabouts, central carriageway islands, build-outs, speed-humps, etc.)
- Where the existing street lighting installation is considered unsatisfactory by virtue of excessive distance between individual street lights
- Where residents, through the consultation process, raise safety or crime and disorder concerns.

8 Monitoring and Evaluation of Potential Health Impacts

8.1 Introduction

8.1.1 This chapter presents the findings of a review, and where appropriate an update or amendment, of the mitigation and enhancement measures of the 2013 HIA Report in light of the evidence reviewed in Chapter 4.

8.1.2 The measures in this chapter of the 2013 HIA Report continue to be applicable.

8.2 Monitoring and evaluation

Indicator (Complaint is an actual incident that occurred; concern is a worry about the potential for the incident to occur in the future)	Phase	Type of Data Collected	Recommended Lead Agency/ies
Residents' complaints/concerns about disruption to access or lack of street lighting	Construction	Number and type of complaints by date complained, date construction activity started and ended, postcode, gender, age and disability (of the resident affected if reported by a friend, relative/neighbour of the person affected)	Local Authority Management Company contracted to provide the LED Street Lighting Sub-contractor installing the LED lighting systems
Residents' complaints/concerns about glare or other health and wellbeing related concerns	Operation	Number and type of complaints by date complained, date LED lighting system became operational, postcode, gender, age and disability (of the resident affected if reported by a friend, relative/neighbour of the person affected)	Local Authority Management Company contracted to provide the LED Street Lighting
Pedestrian, cyclist and motor vehicle driver complaints/concerns about glare or other new lighting system issue	Operation	Number and type of complaints by date complained, date LED lighting system became operational, postcode/name of street/road and area where the issue occurred, gender, age and	Local Authority Management Company contracted to provide the LED

Indicator (Complaint is an actual incident that occurred; concern is a worry about the potential for the incident to occur in the future)	Phase	Type of Data Collected	Recommended Lead Agency/ies
		disability (of the person affected if reported by a friend, relative/neighbour of the person affected)	Street Lighting
Residents' representative sample telephone survey – 6 months and 1 year from date of operation	Operation	Questions about whether they like the new lighting or not, why do they like it, what they think about the quality of the light, whether they have had any problems with the light in the last 6months, how could the lighting be improved for them and their neighbourhood	Local Authority Management Company contracted to provide the LED Street Lighting
Complaints/concerns/compliments expressed by other local stakeholders e.g. environmental groups, health groups, residents' associations, business groups, voluntary groups, charities, etc.	Construction	Number and type of complaints/compliments by date complained, date construction activity started and ended, postcode/name of street/road and area where the issue occurred, name of person reporting, organisation, type of organisation, organisation's concern/role in bringing this forward	Local Authority Management Company contracted to provide the LED Street Lighting Sub-contractor installing the LED lighting systems
Complaints/concerns expressed by other local stakeholders e.g. environmental groups, health groups, residents'	Operation	Number and type of complaints by date complained, date LED lighting system became operational, postcode/name of street/road and	Local Authority Management Company contracted

Indicator (Complaint is an actual incident that occurred; concern is a worry about the potential for the incident to occur in the future)	Phase	Type of Data Collected	Recommended Lead Agency/ies
associations, business groups, voluntary groups, charities, etc.		area where the issue occurred, name of person reporting, organisation, type of organisation, organisation's concern/role in bringing this forward	to provide the LED Street Lighting
New research findings on LED street lighting and health and wellbeing published in a scientifically and/or governmentally recognised peer-reviewed scientific journal and/or undertaken by a recognised and respected individual/team of scientists.	Operation	Number and type of health issues raised, research team/organisation that undertook the research, the quality of the study methodology and methods used, the finding and their epidemiological significance, feedback from Public Health England on the research, assessment of the implications of the findings in relation to the LED Street Lighting	Local Authority

9 Conclusion

9.1.1 Overall, the conclusions of the 2013 HIA Report remain valid.

9.1.2 This review did not identify any major new research that changes the findings of the previous 2013 HIA Report.

9.1.3 Though there is some research that suggests a relationship between exposure to artificial lighting, and blue-rich white lighting, and possible physical and mental health and wellbeing effects, the research evidence is weak, and these are not likely to occur because of the LED street lighting because of the type and intensity of the light likely to be emitted and the low duration and intermittent pattern of exposure that almost all Trafford residents, workers and visitors are likely to have to LED street lighting.

9.1.4 The LED street lighting in Trafford has, overall, no (neutral) or a minor positive health and wellbeing impact for the residents, workers and visitors of Trafford compared to the existing non-LED type of street lighting being used.

9.1.5 The health impact of 'cool' or blue-rich white LED street lighting, at 5700K, is likely to be similar to that of existing non-LED lighting because the contribution of the exposure of residents to street lighting will be a small proportion of their overall exposure to artificial lighting indoors and other types of lighting outdoors.

9.1.6 There is no scientific evidence supporting the need to remove the LED street lighting currently in place in Trafford

Appendix A:

Search Strategy for the Evidence Review

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Search Strategy for the Evidence Review

Aims of review

The aim of this review is to search for recent evidence on the actual and potential health and wellbeing impacts of LED street lighting.

Background

A systematic review was not within the scope of this project. Instead the search aim was to be broad and encompass as much literature as possible before deciding on the value of including or excluding a source document. This has the potential for greater bias and so wherever appropriate actual extracts from the findings of key documents are presented and all review reports identified have been included in the review. The focus is on emerging new evidence i.e. primary and secondary literature from 2013 or 1014.

Review methods

1. Identification of key secondary scientific research reviews and primary research articles on the health effects of:
    - LED street lighting
    - LED lighting
    - Artificial light
2. Research studies and surveys of LED street lighting pilots and programmes.

Search

Google, Google Scholar, Pubmed, Web of Knowledge, Medline and Scopus were searched. With Google and Google Scholar the first 500 search items were reviewed for relevance. For Web of Knowledge and Scopus all the search items were reviewed for relevance.

The main search terms used were:

LED street light/ing health/health impacts

street light/ing health

artificial light/ing health

"light at night" health

"LED street lighting" "health risk"

LED light health risk

"LED street lighting" health

LED artificial light health effects

LED street lighting sensory visual impairment disability

LED street lighting cause glare in elderly

driver glare from LED lighting

LED street lighting accident study

"LED lighting" brain

LED street lighting trial community surveys

LED street lighting trial assessment report

"LED street lighting" site:gov.uk

health risks indoor lighting

review scientific literature light human health -wind -EMF (- means that the following terms are excluded, in this wind and EMF were excluded from the search results)

Search Years

2013-2014.

Language

Only English language documents were considered.

Inclusion or exclusion criteria

Only reviews and peer-reviewed scientific journal articles written by scientific teams who could be searched for online and verified or sponsored or funded by governmental or other scientifically credible bodies, e.g. American Medical Association, were considered for inclusion in the evidence review. Animal studies, plant studies, studies of medical procedures and in-vitro studies were excluded.

Evaluation of quality

We did not conduct a systematic quality review of the studies and articles identified in the review as this was beyond the scope of this rapid HIA. As stated previously the aim was to be as broad as possible and to use scientifically credible secondary reviews as filters for the quality of the primary research in this area.

Search

Between 2013 to present (search for recent/emerging evidence) – "Health" OR "Accident" OR "Glare" OR "Visual impairment" OR "Visual discomfort" AND "light emitting diode" OR "light at night" OR "artificial light" OR "Blue light"

Results: 354

Relevant after reading title and abstract: 36

Results (N = 36)

Light exposure at night is associated with subclinical carotid atherosclerosis in the general elderly population: The HEIJO-KYO cohort.

Circadian disrupting exposures and breast cancer risk: a meta-analysis.

Light at night and breast cancer risk among California teachers.

Association between light exposure at night and insomnia in the general elderly population: The HEIJO-KYO cohort.

Preliminary results of shift work and cardiovascular risk factors: analysing baseline data of a prospective night shift worker cohort in Shenzhen, China.

Long-term nightshift work and breast cancer risk in Hong Kong women: results update.

Colorectal cancer risk and shift work in a population-based case-control study in Spain (MCC-Spain).

Melatonin and the circadian system: contributions to successful female reproduction.

The bright-nights and dim-days of the urban photoperiod: implications for circadian rhythmicity, metabolism and obesity.

Light exposure at night, sleep duration, melatonin, and breast cancer: a dose-response analysis of observational studies.

Circadian variation of melatonin, light exposure, and diurnal preference in day and night shift workers of both sexes.

Association between light exposure at night and nighttime blood pressure in the elderly independent of nocturnal urinary melatonin excretion.

Breast cancer and circadian disruption from electric lighting in the modern world.

Contrasting trends in light pollution across Europe based on satellite observed night time lights.

A cross-sectional analysis of light at night, neighborhood sociodemographics and urinary 6-sulfatoxymelatonin concentrations: implications for the conduct of health studies.

Adverse health effects of nighttime lighting: comments on American Medical Association policy statement.

Evaluating potential spectral impacts of various artificial lights on melatonin suppression, photosynthesis, and star visibility.

Exposure to light at night and risk of depression in the elderly.

Effects of artificial dawn and morning blue light on daytime cognitive performance, well-being, cortisol and melatonin levels.

A case-referent study: light at night and breast cancer risk in Georgia.

Night work and breast cancer estrogen receptor status--results from the German GENICA study.

Methylation alterations at imprinted genes detected among long-term shift workers.

Relationship between intensity of night shift work and antioxidant status in blood of nurses.

Shift work and cancer risk: potential mechanistic roles of circadian disruption, light at night, and sleep deprivation.

Exposure to light at night, nocturnal urinary melatonin excretion, and obesity/dyslipidemia in the elderly: a cross-sectional analysis of the HEIJO-KYO study.

Circadian gene expression in peripheral blood leukocytes of rotating night shift nurses.

The bright-nights and dim-days of the urban photoperiod: Implications for circadian rhythmicity, metabolism and obesity

The Relationship Between Obesity and Exposure to Light at Night: Cross-Sectional Analyses of Over 100,000 Women in the Breakthrough Generations Study

Light at night: A new kind of environment pollution

The effect of nocturnal blue light exposure from light-emitting diodes on wakefulness and energy metabolism the following morning.

A comparison of blue light and caffeine effects on cognitive function and alertness in humans.

Effects of artificial dawn and morning blue light on daytime cognitive performance, well-being, cortisol and melatonin levels.

Does the installation of blue Lights on train platforms shift suicide to another station?: Evidence from Japan

Does the installation of blue lights on train platforms prevent suicide? A before-and-after observational study from Japan

Effects of blue light and caffeine on mood

Another blue light hazard?

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