WHAT ARE THE EFFECTS OF ARTIFICIAL LIGHT ON HUMAN HEALTH? AN EVIDENCE BRIEF

JULY 2023

Team members: German Alarcon Garavito, Fiona Bennin, Phoebe Barnett, prof Cecilia Vindrola-Padros

Rapid Research Evaluation and Appraisal Lab (RREAL)

Department of Targeted Intervention
University College London (UCL)
Charles Bell House
43-45 Foley Street
London
W1W 7TY
@RREALwork
https://www.rapidresearchandevaluation.com/

Contact: Dr Cecilia Vindrola
c.vindrola@ucl.ac.uk

EXECUTIVE SUMMARY

AIM

The purpose of this evidence review was to rapidly gather evidence on the effects of artificial light on human health.

DESIGN

This rapid review of evidence was conducted over 10 weeks (06th March to 14th May2023) and includes both peer-reviewed and grey literature, published in the last ten years (January2013-March2023). It does not include any language limitations.

ABOUT THIS PROJECT

This rapid evidence review was produced as part of a pilot project to develop robust methods for producing rapid reviews of research for Parliamentarians. The Parliamentary Office of Science and Technology (POST) has worked with the Rapid Research, Evaluation and Appraisal Lab (RREAL), International Public Policy Observatory (IPPO), and the Capabilities in Academic Policy Engagement (CAPE) to produce rapid research synthesis based on comprehensive searches of academic databases. We have worked directly with Parliamentary select committees to conduct fast turnaround summaries of available research literature - informed by systematic review methods - delivered in partnership with Early Career Researchers from UK universities. The research was supported by Jonathan Breckon (POST, IPPO, CAPE Policy Fellow), Sarah Bunn (POST), Clare Lally (POST), Matthew Manning (Lords Science and Technology Committee), Thomas Hornigold (Lords Science and Technology Committee). We would also like to thank Professor Russell G. Foster (University of Oxford) and Dr. Hannah Dalgeish (University of Oxford) for their valuable feedback and comments on drafts of the report. Any errors are, however, the authors' own.

DISCLAIMER

This Rapid Evidence Assessment (REA) has been produced in consultation with the Parliamentary Office of Science and Technology (POST) to improve the conduct of scrutiny in Parliament; it is not, and should not be relied on as, advice. Neither the House of Lords nor the House of Commons are responsible for any information contained in this REA, or for its accuracy, and will not be liable for any errors or omissions or for any loss or damage arising from its use. The REA is the sole responsibility of the authors.

RESULTS

- Light pollution is classified by location (indoor or outdoor), colour (short or long wave) and magnitude (bright or dim), while the types of light pollution are grouped as light trespass, light clutter, glare, and skyglow.
- White phosphor-coated light-emitting diodes (WPCLEDs or white LEDs) are a common source of outdoor artificial light at night.
- Negative impacts of light pollution include suppression of melatonin and disruption of the circadian rhythm, which might contribute to:
  - sleep disorders, mood and mental health disorders, obesity, cancer, cardiovascular disease, and difficulties with fertility and reproduction.
- Studies attribute the worsening of light pollution to the increased use of LEDs and the urbanisation of towns and cities.
- Some types of air pollution, such as smoke, can also worsen light pollution by causing light to scatter and brighten the night sky further.
- Quality assessment of included evidence showed problems with sample sizes, and controllingfactors that can affect measurements. Some claims from the included literature have been contested recently due to limited empirical evidence (e.g., melatonin's role as an anti-cancer agent and the influence of light pollution).

RECOMMENDATIONS

- Individual recommendations include:
  - ◊ Exposure to natural light in the evening, or using a small, low-power lamp to transition into darkness.
  - ◊ Exercising regularly for better sleep and preventing diseases.
- Societal recommendations include:
  - ◊ Using light shielding techniques and installing full cut-off fixtures on streetlights to direct light downward.
  - ◊ Promoting green building design to allow access to natural daylight in indoor environments.

BACKGROUND

The use of artificial lighting is becoming increasingly prevalent with modern lighting solutions such as Light-Emitting Diodes (LEDs) [1]. LEDs are more energy efficient but tend to be more harmful by emitting more light of shorter wavelengths [2] and are increasingly becoming the standard lighting source of choice. Artificial light allows the time which can be used to work or socialise to be extended past the hours of natural light [3]. However, when natural light levels are altered or reduced because of artificial sources, this produces light pollution, levels of which are also increasing [4]. According to the International Dark-Sky Association,light pollution is aside effect of industrial civilization, where the inappropriate or excessive use of artificial light might cause dangerous environmental consequences for humans, wildlife, and climate (5). The health conditions linked to light pollution range from sleep difficulties to an increased risk of developing some cancers[4]. This rapid evidence review aimed to summarise the evidence on the effects of artificial light on human health.

RESEARCH QUESTIONS GUIDING THE REVIEW

1 What is the state of the evidence base regarding the causes and impacts of light pollution in the UK as it relates to human health?

a. What are the mechanisms by which light pollution has an impact on human health – for example, by disrupting circadian rhythms? What are the negative impacts it can have?

b. What are the primary sources of light pollution and how well do we understand them? Is there evidence regarding which types of artificial light, in terms of frequency, duration of exposure, or intermittency, are the most harmful?

c. Is there evidence that light pollution is worsening – for example, with the introduction of LEDs and cheaper forms of lighting, or lighting with a different wavelength spectrum?

2 What are the interventions that have been used to mitigate the effects of light pollution and what are their reported effects?

TYPES AND PRIMARY SOURCES OF LIGHT POLLUTION

Sources of light pollution vary and are classified in a number of ways in the literature. They can be grouped by location (indoor or outdoor light), or the magnitude of the light wave (either short or long). Typically, light pollution can beclassified as:

- **Light trespass** - arises when streetlights illuminate above the ground-level, reaching homes where most people are asleep (6).
- **Light clutter** - the excessive alignment of lights (7).
- **Glare** - occurs when light is excessively bright and generates discomfort (8).
- **Skyglow** – occurs when light reflects from the ground and generates a luminous background (9)(6,7,10–12).

White phosphor-coated light-emitting diodes (WPCLEDs or white LEDs) are the main source of artificial light at night (ALAN) both outdoors and indoors. LEDs are more commonly used for domestic, occupational, street, and stadium lighting (7).

Furthermore, there is a differentiation between domestic and public/industrial use. For public/industrial use, light intensity is higher due to its extended purpose for safety and preventing crime (13), but this light often exceeds the minimum emission requirementson road lighting and traffic signals in the European Union(14).

Some reported sources of ALAN for public/industrial use include lighting of streets, highways, railways, residential and commercial buildings, industries, and billboards (15,16), while for domestic use, sources include indoor electric lights (including bedside night lights, desk lamps, etc) and electronic device screens, among others (17,18).

NEGATIVE IMPACTS OF LIGHT POLLUTION AND THEIR MECHANISMS

The main mechanisms by which light pollution impacts human health are **1)** the suppression of melatonin and **2)** the disruption of the circadian rhythm (19–21).

1. Melatonin is a hormone released from the pineal gland in the brain and is naturally released in response to decreasing levels of light (both natural and artificial).It is a widely held view that melatoninis responsible for increasing tiredness and regulating sleep cycles (7,11,22,23). Light at night (LAN) has been found to suppress melatonin secretion (24–26), which is particularly sensitive to blue light (27). Most forms of outdoor illumination contain metal halide, mercury vapour, fluorescent, and blue-white LED illumination. All forms of indoor lighting and electronic devices (TV, cellular and smartphones, and other electrical devices) use blue light and have Short Wavelength Light (SWL) emissions, which have a considerable influence on melatonin production (13). Melatonin disruption results in the disruption of the body's circadian rhythms and processes (6).
2. The circadian rhythm is responsible for regulating the body's hormone production, cell regulation, brain processes and other biologic activities e.g., body temperature regulation, appetite, etc. (8,28). As a result, any changes to this rhythm, e.g., suppressed melatonin, can cause sleep andmetabolic irregularities (9). When exposed to light pollution, melatonin is reduced and there are changes in circadian rhythm. This results in light working as an endocrine disruptor (something that may mimic or interfere with the body's hormones) and a general stressor to the body's systems (15). This disrupted daily rhythm impacts sleep cycles and weakens immune systems. It also changes how oestrogen is used in the body, which increases susceptibility to infectious diseases and oestrogen-linked cancers (15). Melatonin has been reported to be an anti-carcinogen and can eradicate oxygen radicals (an unstable molecule, which if spread, can result in the death of certain cells in the body). Therefore, melatonin disruption reduces its efficacy and further increases susceptibility to developing cancer and Parkinson's disease when exposed to LAN (29). Changes in circadian cell processes, sleep disruption and behaviour (e.g., eating at irregular times) are all contributors to the risk of obesity (16,30–32), as well as mood disorders and cardiovascular disease (17,33–36). The literature suggests that the way in whichlight pollution impacts health is implicated in a range ofnegative health outcomes. The main health impacts can be categorised into:
    1) Sleep disorders,
    2) Mood/ mental health disorders,
    3)Cancer, obesity, and cardiovascular disease and
    4) Difficulties with fertility and reproduction.

SLEEP DISORDERS

Light pollution impacts negatively on sleep, specifically,its duration and quality (37). Exposure to screens at night 1 hour before bedtime disrupts sleep ability and quality by lengthening sleep latency (time it takes for a person to fall asleep). This can increasein the length and number of nocturnal awakenings, reducing sleep duration and efficiency due to the decrease of time spent asleep while in bed(35,38,39). When sleep is severely impacted, sleep deprivation can lead to the onset of anxiety, depression, and other mental health disorders (40).

MOOD/ MENTAL HEALTH DISORDERS

The increasedprevalence of mood/ mental health disorders can be linked to increased disruptions in sleep, resulting from exposure to light pollution, as discussed previously.However, there is also evidence that suggests that exposure to indoor and outdoor ALAN increases the risk of bipolar disorder, depression, and suicidal behaviour (21,41–43). This risk varies with the level of exposure since it has been observed that increased exposure to outdoor ALAN increases the odds of having depressive symptoms and exhibiting suicidal behaviours (21).

CANCER, OBESITY AND CARDIOVASCULAR DISEASE

As previously mentioned, melatonin is believed to be an anti-carcinogenic agent (which halts the spread of cancer). Therefore, light pollution increases the risk of cancer due to the suppression of melatonin in the blood (9). There are numerous articles detailing the association between ALAN and the risk of breast cancer (6,10,13,44–48). However, there is also debated evidence to suggest that there is a link between ALAN and other cancers, including prostate (6–8,49), colon (50,51), thyroid (30), Non-Hodgkin's Lymphoma (52,53), and pancreatic cancer (24).

Selected studies generally attributed this relationship to hypotheses such as changes in melatonin production and suppression, melatonin properties as an oncostatic agent(44), and circadian disruption(44,50).Circadian disruption because ofshiftwork was labelled asa probable carcinogenic to humans in 2007, by the International Agency for Research on Cancer (IARC) (50).

Furthermore, there has been a growing number of studies reporting on the association between ALAN and obesity (10,16,31,32), diabetes (54) and cardiovascular disease (10,55,56).

FERTILITY AND REPRODUCTION

Evidence suggeststhat there is a link between nocturnal light exposure (e.g., in night shift work) and impairments in reproduction and fertility, arising from circadian shifts(57). In women, exposure to ALAN and changes in sleep cycles are associated with disruptions to hormone secretion, changes in lengths of menstrual cycles, risk of miscarriage, preterm birth, and low infant birth weight (57). In men, there is a suggested link between night shift work and male fertility issues, although the link to ALAN is not as well evidenced as the link for females.(57).

WORSENING OF LIGHT POLLUTION

Studies that reported how light pollution is worsening, associated this situation with the increased use of LEDs and the urbanisation of towns and cities. One study reported that in 2017, satellite-observable light emissions had increased by 49% over the previous 25 years (58), whileanother quantitative cross-sectional survey found that self-reported perceptions of light pollution were that it had not worsened (59).

LEDS

The use of LEDs has increased from 3% to over 50% in the last ten years, and it is expected to reach 99% by 2030(60). Light pollution is made worse by the increasing use of LEDs because of the tendency of these forms of light to be either blue or white light (61), which are thought to have a greater impact on suppressing melatonin (6,7,62). These wavelengths have been associated with worse health outcomes, such as more severely disrupted circadian rhythms, retinal toxicity (increased toxins in the retina of the eye) (63), and breast cancer morbidity (the increased rate of the disease in the population)(15).

INCREASING URBANISATION

The increasing urbanisation of towns and cities has also been reported to exacerbate light pollution, as urban areas are associated with the experience of less natural light during the day (due to the presence of more artificial light) and more artificial light at night (37,51,64,65). For example, one quantitative cross-sectional survey reported that in addition to light pollution being higher in urban areas, this light pollution subsequently had a greater impact on sleep quality in those living in urban areas compared to rural areas (37).

AIR POLLUTION

Reports have also argued that certain types of air pollution such as smoke, can further exacerbate light pollution because it can cause light to scatter in different directions, brightening "night" skies further (3). However, with a small number of research discussing this interaction, caution must be applied, as the findings might not be conclusive.

INTERVENTIONS TO MITIGATE THE EFFECTS OF LIGHT POLLUTION

The literature highlighted some mitigation strategies to reduce light pollution and their impacts. They were divided into individual and societal strategies as depicted below. Previous studies have set evening and night-time as the 2 hours before going to sleep, and the actual hours of sleep, respectively (83).
RECOMMENDATIONS FOR INDIVIDUALS IDENTIFIED IN THE LITERATURE INCLUDE:

EVENING LIGHT RECOMMENDATIONS:

- The melanopic EDI is indicative for how the body reacts to light. The recommended melanopic EDI is 250 lux, which ideally should be provided by natural daylight (64).
- If additional electric lighting is required, the polychromatic white light should have a spectrum that is enriched in a shorter wavelength (64).
- Exercising regularly for better sleep and preventing diseases (17,33).
- Installation of a free mobile application Twilight (http://twilight.urbandroid.org) on mobile phones or similar (67).

NIGHT-TIME LIGHT RECOMMENDATIONS

- Turn off lights, especially in times when they may not be needed (55).
- Limit exposure to blue light or filter it out as much as possible at night e.g., light filtering glasses, dimming screens, and night-time filters using warmer bulbs (43,46,47,55,63,66).
- Exposure to natural light in the evening, or using a small, low-power lamp to transition into darkness (19,54).
- In consultation with your physician, increase melatonin concentrations with melatonin supplements taken at night (46,47).
- Starting at least 3 hours before bedtime, the recommended maximum melanopic EDI is ten lux. To help achieve this, the white light should have a spectrum depleted in short wavelengths (64).
- Invest in blackout curtains or a sleep mask to create the darkest environment possible when you go to bed (27,40,51,67).

RECOMMENDATIONS FOR SOCIETY IDENTIFIED IN THE LITERATURE INCLUDE:

- Using light shielding techniques and installing full cut-off fixtures on streetlights to direct light downward (8,11,68).
- Energy-efficient lights (55).
- Smart city techniques (e.g., sensor-controlled light shut-off when the area is not in use or adaption to meteorological conditions) (55).
- Motion sensors be installed so they only come on when needed, or even better, only turned off when sensing heat, not movement (26,69).
- Curfew period, where a further limitation is applied for late night (i.e., 11 pm) (70).
- Technology: Some researchers suggest the creation of a City Emission Functions (CEFs) database with the help of radiometry leading to a new phase in light pollution research with significant cost-effectiveness and advanced accuracy of night sky brightness predictions (10).
- Promoting green building design to allow access to natural daylight in indoor environment (70).

INDIVIDUAL STRATEGIES:

Evening light recommendations:

- The melanopic EDI is indicative for how the body reacts to light. The recommended melanopic EDI is 250 lux, which ideally should be provided by natural daylight (64).
- If additional electric lighting is required, the polychromatic white light should have a spectrum that is enriched in a shorter wavelength (64).
- Regular physical activity may be a good option for individuals living with elevated levels of indoor LAN exposure, for improved sleep and preventing diseases such as cardiovascular disease and hypertension

(17,33).

- Installation of a free mobile application Twilight (http://twilight.urbandroid.org) on mobile phones or similar(67).

Night-time light recommendations

- Turn off lights, especially in times when they may not be needed (55)
- Limit exposure to blue light or filter it out as much as possible at night e.g., light filtering glasses, dimming screens, and night-time filters using warmer bulbs (43,46,47,55,63,66).
- Exposure to natural light in the evening, or using a small, low-power lamp to transition into darkness (19,54).
- In consultation with your physician, increase melatonin concentrations with melatonin supplements taken at night (46,47).
- Starting at least 3 hours before bedtime, the recommended maximum melanopic EDI is ten lux. To help achieve this, the white light should have a spectrum depleted in short wavelengths (64).
- Invest in blackout curtains or a sleep mask to create the darkest environment possible when you go to bed (27,40,51,67).

SOCIETAL STRATEGIES

- Light shielding (sending light to the ground instead of the horizon or outside the area to be lit). The most used fixtures for street lighting are the drop lens cobra luminaire. Full cut-off fixtures need to be installed on drop lens cobra luminaire lenses (on streetlights) to make sure the light is directly downward (8,11,68).
- Energy-efficient lights (55).
- Smart city techniques (e.g., sensor-controlled light shut-off when the area is not in use or adaption to meteorological conditions) (55).
- Motion sensors be installed so they only come on when needed, or even better, only turned off when sensing heat, not movement (26,69).
- Curfew period, where a further limitation is applied for late night (i.e., 11 pm) (70).
- Technology: Some researchers suggest the creation of a City Emission Functions (CEFs) database with the help of radiometry leading to a new phase in light pollution research with significant cost-effectiveness and advanced accuracy of night sky brightness predictions (10).
- Green building design promotes daylight access in an indoor built environment (70).

GLOSSARY

Light-emitting diodes (LEDs)	Asemiconductor device that emits light when current flows through it.
Minimum emission requirements	Applied to a wide-ranging list of activities which result in atmospheric emissions that have, or may have, a significant detrimental effect on the environment, including health, social conditions, economic conditions, ecological conditions, or cultural heritage(71).
Circadian rhythm	A natural, internal process that regulates hormone release, eating habits and body temperature, including the 24-hour sleep-wake cycle(72).
Circadian disruption	Any disruption in the 24-hour circadian rhythm.
Pineal gland	A tiny gland found in the brain, responsible for secreting melatonin.
Blue white LED illumination	Using a blue LED with a phosphor coating to convert blue light to white light by a process called fluorescence(73).
Metabolic irregularities	The metabolism is responsible for taking and making the energy from the food we eat. Irregularities occur when abnormal chemical reactions in the body disrupt this process(74).
Endocrine disruptors	Chemicals, both natural and human-made, may mimic or interfere with the body's hormones, known as the endocrine system. These chemicals are linked with developmental, reproductive, brain, immune, and other problems(75).
Oestrogen-linked cancers	Cancers such as breast cancer, ovarian cancer and endometrial (uterine) cancer, which rely on oestrogen to develop and grow.
Anti-carcinogen	Preventing or delaying the development of cancer
Oxygen radical	A type of unstable molecule that contains oxygen and that easily reacts with other molecules in a cell. A build-up of oxygen radicals in cells may cause damage to DNA, RNA, and proteins, and may cause cell death.
Cardiovascular disease	A disease of the heart or blood vessels.
Sleep latency	The time is takes for a person to fall asleep after turning off the lights.
Oncostatic	Halts the spread of cancer (a synonym for anti-carcinogen)
Retinal toxicity	Damage to the retina, usually from strong doses of certain medications
Morbidity	Refers to having a disease or a symptom of disease, or to the amount of disease within a population.
Melanopic EDI	The circadian metric that has been adopted by the international commission on lighting (CIE)(76).
Polychromatic	Being or relating to radiation that is composed of more than one wavelength.
City Emissions Functions (CEFs)	The upward intensity angular distribution function of ground-based light sources. In some cases, CEF is also interpreted in terms of luminous intensity distribution(77).

REFERENCES

001 Bennie J, Davies TW, Inger R, Gaston KJ. Mapping artificial lightscapes for ecological studies. Chisholm R, editor. Methods Ecol Evol [Internet]. 2014 Jun 29;5(6):534–40. Available from: https://onlinelibrary.wiley.com/doi/10.1111/2041-210X.12182

002 AMA (American Medical Association, Council on Science and Public Health. Human and Environmental Effects of Light Emitting Diode (LED) Community Lighting. REPORT OF THE COUNCIL ON SCIENCE AND PUBLIC HEALTH [Internet]. 2016 [cited 2023 May 2]; Available from: https://policysearch.ama-assn.org/councilreports/downloadreport?uri=/councilreports/a16_csaph2.pdf

003 Chepesiuk R. Missing the Dark: Health Effects of Light Pollution. Environ Health Perspect [Internet]. 2009 Jan;117(1). Available from: https://ehp.niehs.nih.gov/doi/10.1289/ehp.117-a20

004 Falchi F, Furgoni R, Gallaway TA, Rybnikova NA, Portnov BA, Baugh K, et al. Light pollution in USA and Europe: The good, the bad and the ugly. J Environ Manage [Internet]. 2019 Oct;248:109227. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0301479719309296

005 International Dark-Sky Association. Light Pollution [Internet]. 2016 [cited 2023 May 23]. Available from: https://www.darksky.org/light-pollution/

006 Grose M. Artificial light at night: a neglected population health concern of the built environment. Health Promotion Journal of Australia [Internet]. 2014 Dec;25(3):193–5. Available from: http://doi.wiley.com/10.1071/HE14045

007 Dutfield S. Light pollution: Environmental impact and health risks | Live Science [Internet]. LiveScience. 2022 [cited 2023 Mar 6]. Available from: https://www.livescience.com/light-pollution

008 Arcadia. 15 Key Facts & Statistics About Light Pollution [Internet]. Arcadia. 2017 [cited 2023 Mar 7]. Available from: https://blog.arcadia.com/15-key-facts-statistics-light-pollution/

009 Bjelajac D, Đerčan B. Artificial light at night as an unrecognized threat to protected areas of Autonomous Province of Vojvodina (North Serbia). Zbornik radova Departmana za geografiju, turizam i hotelijerstvo [Internet]. 2019;(48–1):46–56. Available from: https://scindeks.ceon.rs/Article.aspx?artid=1452-01331948046B

010 Kumar P, Ashawat MS, Pandit V, Sharma DK. Artificial Light Pollution at Night: A risk for normal circadian rhythm and physiological functions in humans. Current Environmental Engineering. 2019;6(2):111–25.

011 Pandey A. Light pollution [Internet]. Slideshare.net. 2013 [cited 2023 Mar 7]. Available from: https://www.slideshare.net/adish88/light-pollution-29009565

012 Rajkhowa R. Light pollution and impact of light pollution. international Journal of Science and Research (IJSR) [Internet]. 2014 [cited 2023 Mar 6];3(10):861–7. Available from: www.ijsr.net

013 Keshet-Sitton A, Or-Chen K, Huber E, Haim A. Illuminating a Risk for Breast Cancer: A Preliminary Ecological Study on the Association Between Streetlight and Breast Cancer. Integr Cancer Ther. 2017 Dec;16(4):451–63.

014 LeTallec T. What is the ecological impact of light pollution? - Encyclopedia of the Environment [Internet]. Encyclopedia of the Environment. 2019 [cited 2023 Mar 7]. Available from: https://www.encyclopedie-environnement.org/en/life/what-is-the-ecological-impact-of-light-pollution/

015 Rybnikova N, Portnov BA. Population-level study links short-wavelength nighttime illumination with breast cancer incidence in a major metropolitan area. Chronobiol Int [Internet]. 2018 Sep 2;35(9):1198–208. Available from: https://www.tandfonline.com/doi/full/10.1080/07420528.2018.1466802

016 Rybnikova NA, Haim A, Portnov BA. Does artificial light-at-night exposure contribute to the worldwide obesity pandemic? Int J Obes [Internet]. 2016 May 22;40(5):815–23. Available from: https://www.nature.com/articles/ijo2015255

017 Xu YX, Zhang JH, Tao FB, Sun Y. Association between exposure to light at night (LAN) and sleep problems: A systematic review and meta-analysis of observational studies. Science of The Total Environment [Internet]. 2023 Jan;857(Pt 1):159303. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0048969722064026

018 Cao M, Xu T, Yin D. Understanding light pollution: recent advances on its health threats and regulations.

Journal of Environmental Sciences. 2022 May;127:589–602.

019 Suni E. Light & Sleep: Effects on Sleep Quality | Sleep Foundation [Internet]. Sleep Foundation. 2023 [cited 2023 Mar 7]. Available from: https://www.sleepfoundation.org/bedroom-environment/light-and-sleep

020 Blume C, Garbazza C, Spitschan M. Effects of light on human circadian rhythms, sleep and mood. Somnologie [Internet]. 2019 Sep 20 [cited 2023 Mar 7];23(3):147–56. Available from: https://osf.io/qcfkr/

021 Min J young, Min KB. Outdoor light at night and the prevalence of depressive symptoms and suicidal behaviors: A cross-sectional study in a nationally representative sample of Korean adults. J Affect Disord [Internet]. 2018 Feb;227:199–205. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0165032717321432

022 Cho JR, Joo EY, Koo DL, Hong SB. Let there be no light: the effect of bedside light on sleep quality and background electroencephalographic rhythms. Sleep Med. 2013 Dec;14(12):1422–5.

023 Cho CH, Lee HJ, Yoon HK, Kang SG, Bok KN, Jung KY, et al. Exposure to dim artificial light at night increases REM sleep and awakenings in humans. Chronobiol Int. 2016;33(1):117–23.

024 Xiao Q, Jones RR, James P, Stolzenberg-Solomon RZ. Light at Night and Risk of Pancreatic Cancer in the NIH-AARP Diet and Health Study. Cancer Res [Internet]. 2021 Mar 15;81(6):1616–22. Available from: https://aacrjournals.org/cancerres/article/81/6/1616/670526/Light-at-Night-and-Risk-of-Pancreatic-Cancer-in

025 Xiao Q, Gee G, Jones RR, Jia P, James P, Hale L. Cross-sectional association between outdoor artificial light at night and sleep duration in middle-to-older aged adults: The NIH-AARP Diet and Health Study. Environ Res [Internet]. 2020 Jan;180:108823. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0013935119306206

026 Weule G. Light pollution is bad for us and for wildlife. So what can we do to solve the problem? - ABC News. ABC news [Internet]. 2020 [cited 2023 Mar 7]; Available from: https://www.abc.net.au/news/science/2020-06-20/light-pollution-is-bad-for-us-and-for-wildlife/12373776

027 National Geographic Society. Light Pollution [Internet]. National Geographic. 2022 [cited 2023 Mar 6]. Available from: https://education.nationalgeographic.org/resource/light-pollution/

028 Filmer J. Light pollution: How does it impact people? [Internet]. Futurism. 2013 [cited 2023 Mar 7]. Available from: https://futurism.com/light-pollution-how-does-it-impact-people

029 Lai KY, Sarkar C, Ni MY, Cheung LWT, Gallacher J, Webster C. Exposure to light at night (LAN) and risk of breast cancer: A systematic review and meta-analysis. Science of The Total Environment [Internet]. 2021 Mar;762:143159. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0048969720366894

030 Zhang D, Jones RR, James P, Kitahara CM, Xiao Q. Associations between artificial light at night and risk for thyroid cancer: A large US cohort study. Cancer [Internet]. 2021 May 8;127(9):1448–58. Available from: https://onlinelibrary.wiley.com/doi/10.1002/cncr.33392

031 Zhang D, Jones RR, Powell-Wiley TM, Jia P, James P, Xiao Q. A large prospective investigation of outdoor light at night and obesity in the NIH-AARP Diet and Health Study. Environmental Health [Internet]. 2020 Dec 1;19(1):74. Available from: https://ehjournal.biomedcentral.com/articles/10.1186/s12940-020-00628-4

032 Muscogiuri G, Poggiogalle E, Barrea L, Tarsitano MG, Garifalos F, Liccardi A, et al. Exposure to artificial light at night: A common link for obesity and cancer? Eur J Cancer [Internet]. 2022 Sep;173:263–75. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0959804922003549

033 Xu YX, Zhou Y, Huang Y, Yu Y, Li JY, Huang WJ, et al. Physical activity alleviates negative effects of bedroom light pollution on blood pressure and hypertension in Chinese young adults. Environmental Pollution [Internet]. 2022 Nov;313:120117. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0269749122013318

034 Nguyen TPL, Peña-García A. Users' Awareness, Attitudes, and Perceptions of Health Risks Associated with Excessive Lighting in Night Markets: Policy Implications for Sustainable Development. Sustainability [Internet]. 2019 Nov 1;11(21):6091. Available from: https://www.mdpi.com/2071-1050/11/21/6091

035 Wang T, Kaida N, Kaida K. Effects of outdoor artificial light at night on human health and behavior: A literature review. Environmental Pollution [Internet]. 2023 Apr;323:121321. Available from: https://

linkinghub.elsevier.com/retrieve/pii/S0269749123003238

036 Wang LB, Gong YC, Fang QL, Cui XX, Dharmage SC, Jalaludin B, et al. Association Between Exposure to Outdoor Artificial Light at Night and Sleep Disorders Among Children in China. JAMA Netw Open [Internet]. 2022 May 20;5(5):e2213247. Available from: https://jamanetwork.com/journals/jamanetworkopen/fullarticle/2792494

037 Lahiri A, Chakraborty A, Roy AS, Dasgupta U, Bhattacharyya K. Effect of light pollution on self-reported sleep quality and its components: Comparative assessment among healthy adult populations in a rural and an Urban area of West Bengal, India. Indian J Public Health [Internet]. 2020;64(3):229. Available from: http://www.ijph.in/text.asp?2020/64/3/229/295788

038 Green A, Cohen-Zion M, Haim A, Dagan Y. Comparing the response to acute and chronic exposure to short wavelength lighting emitted from computer screens. Chronobiol Int [Internet]. 2018 Jan 2;35(1):90–100. Available from: https://www.tandfonline.com/doi/full/10.1080/07420528.2017.1387555

039 Cho Y, Ryu SH, Lee BR, Kim KH, Lee E, Choi J. Effects of artificial light at night on human health: A literature review of observational and experimental studies applied to exposure assessment. Chronobiol Int. 2015;32(9):1294–310.

040 Robb-Dover K. Understanding the Mental Health Impact of Light Pollution [Internet]. FHE Health. 2020 [cited 2023 Mar 7]. Available from: https://fherehab.com/learning/light-pollution-mental-health

041 Tonon AC, Constantino DB, Amando GR, Abreu AC, Francisco AP, de Oliveira MAB, et al. Sleep disturbances, circadian activity, and nocturnal light exposure characterize high risk for and current depression in adolescence. Sleep. 2022 Jul;45(7).

042 Carta MG, Preti A, Akiskal HS. Coping with the New Era: Noise and Light Pollution, Hperactivity and Steroid Hormones. Towards an Evolutionary View of Bipolar Disorders. Clin Pract Epidemiol Ment Health. 2018;14:33–6.

043 Paksarian D, Rudolph KE, Stapp EK, Dunster GP, He J, Mennitt D, et al. Association of Outdoor Artificial Light at Night With Mental Disorders and Sleep Patterns Among US Adolescents. JAMA Psychiatry [Internet]. 2020 Dec 1;77(12):1266. Available from: https://jamanetwork.com/journals/jamapsychiatry/fullarticle/2767698

044 Lamphar H, Kocifaj M, Limón-Romero J, Paredes-Tavares J, Chakameh SD, Mego M, et al. Light pollution as a factor in breast and prostate cancer. Science of The Total Environment [Internet]. 2022 Feb;806(Pt 4):150918. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0048969721059969

045 Planetarium JCW. Light Pollution: The Overuse & Misuse of Artificial Light at Night - JMU [Internet]. James Madison University. Available from: https://www.jmu.edu/planetarium/light-pollution.shtml

046 Walker WH, Bumgarner JR, Becker-Krail DD, May LE, Liu JA, Nelson RJ. Light at night disrupts biological clocks, calendars, and immune function. Semin Immunopathol [Internet]. 2022 Mar 3;44(2):165–73. Available from: https://link.springer.com/10.1007/s00281-021-00899-0

047 Walker WH, Bumgarner JR, Walton JC, Liu JA, Meléndez-Fernández OH, Nelson RJ, et al. Light Pollution and Cancer. Int J Mol Sci [Internet]. 2020 Dec 8;21(24):9360. Available from: https://www.mdpi.com/1422-0067/21/24/9360

048 Keshet-Sitton A, Or-Chen K, Yitzhak S, Tzabary I, Haim A. Light and the City: Breast Cancer Risk Factors Differ Between Urban and Rural Women in Israel. Integr Cancer Ther. 2017 Jun;16(2):176–87.

049 Garcia-Saenz A, Sánchez de Miguel A, Espinosa A, Valentin A, Aragonés N, Llorca J, et al. Evaluating the Association between Artificial Light-at-Night Exposure and Breast and Prostate Cancer Risk in Spain (MCC-Spain Study). Environ Health Perspect [Internet]. 2018 Apr 5;126(4):047011. Available from: https://ehp.niehs.nih.gov/doi/10.1289/EHP1837

050 Garcia-Saenz A, de Miguel AS, Espinosa A, Costas L, Aragonés N, Tonne C, et al. Association Between Outdoor Light-at-night Exposure and Colorectal Cancer in Spain. Epidemiology [Internet]. 2020 Sep;31(5):718–27. Available from: https://journals.lww.com/10.1097/EDE.0000000000001226

051 Stevens RG, Zhu Y. Electric light, particularly at night, disrupts human circadian rhythmicity: is that a problem? Philosophical Transactions of the Royal Society B: Biological Sciences [Internet]. 2015 May 5;370(1667):20140120. Available from: https://royalsocietypublishing.org/doi/10.1098/rstb.2014.0120

052 Zhong C, Franklin M, Wiemels J, McKean-Cowdin R, Chung NT, Benbow J, et al. Outdoor artificial light at night and risk of non-Hodgkin lymphoma among women in the California Teachers Study cohort.

Cancer Epidemiol [Internet]. 2020 Dec;69:101811. Available from: https://linkinghub.elsevier.com/retrieve/pii/S1877782120301454

053 Zhong C, Wang R, Morimoto LM, Longcore T, Franklin M, Rogne T, et al. Outdoor artificial light at night, air pollution, and risk of childhood acute lymphoblastic leukemia in the California Linkage Study of Early-Onset Cancers. Sci Rep [Internet]. 2023 Jan 11;13(1):583. Available from: https://www.nature.com/articles/s41598-022-23682-z

054 Meléndez-Fernández OH, Liu JA, Nelson RJ. Circadian Rhythms Disrupted by Light at Night and Mistimed Food Intake Alter Hormonal Rhythms and Metabolism. Int J Mol Sci [Internet]. 2023 Feb 8;24(4):3392. Available from: https://www.mdpi.com/1422-0067/24/4/3392

055 Münzel T, Sørensen M, Lelieveld J, Hahad O, Al-Kindi S, Nieuwenhuijsen M, et al. Heart healthy cities: genetics loads the gun but the environment pulls the trigger. Eur Heart J [Internet]. 2021 Jul 1;42(25):2422–38. Available from: https://academic.oup.com/eurheartj/article/42/25/2422/6273087

056 Obayashi K, Yamagami Y, Tatsumi S, Kurumatani N, Saeki K. Indoor light pollution and progression of carotid atherosclerosis: A longitudinal study of the HEIJO-KYO cohort. Environ Int. 2019 Dec;133(Pt B):105184.

057 Moralia MA, Quignon C, Simonneaux M, Simonneaux V. Environmental disruption of reproductive rhythms. Front Neuroendocrinol [Internet]. 2022 Jul;66:100990. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0091302222000139

058 Sánchez de Miguel A, Bennie J, Rosenfeld E, Dzurjak S, Gaston KJ. First Estimation of Global Trends in Nocturnal Power Emissions Reveals Acceleration of Light Pollution. Remote Sens (Basel) [Internet]. 2021 Aug 21;13(16):3311. Available from: https://www.mdpi.com/2072-4292/13/16/3311

059 Coogan AN, Cleary-Gaffney M, Finnegan M, McMillan G, González A, Espey B. Perceptions of Light Pollution and its Impacts: Results of an Irish Citizen Science Survey. Int J Environ Res Public Health [Internet]. 2020 Aug 4;17(15):5628. Available from: https://www.mdpi.com/1660-4601/17/15/5628

060 International Energy Agency (IGA). Global lighting sales in the Net Zero Scenario, 2010-2030 – Charts – Data & Statistics - IEA [Internet]. 2022 [cited 2023 May 11]. Available from: https://www.iea.org/data-and-statistics/charts/global-lighting-sales-in-the-net-zero-scenario-2010-2030

061 Sánchez de Miguel A, Bennie J, Rosenfeld E, Dzurjak S, Gaston KJ. Environmental risks from artificial nighttime lighting widespread and increasing across Europe. Sci Adv [Internet]. 2022 Sep 16;8(37). Available from: https://www.science.org/doi/10.1126/sciadv.abl6891

062 Côté-Lussier C, Knudby A, Barnett TA. A novel low-cost method for assessing intra-urban variation in night time light and applications to public health. Soc Sci Med [Internet]. 2020 Mar;248:112820. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0277953620300393

063 Touitou Y, Point S. Effects and mechanisms of action of light-emitting diodes on the human retina and internal clock. Environ Res. 2020 Nov;190:109942.

064 Brown TM, Brainard GC, Cajochen C, Czeisler CA, Hanifin JP, Lockley SW, et al. Recommendations for daytime, evening, and nighttime indoor light exposure to best support physiology, sleep, and wakefulness in healthy adults. PLoS Biol [Internet]. 2022 Mar 17 [cited 2023 Mar 7];20(3):e3001571. Available from: https://www.preprints.org/manuscript/202012.0037/v1

065 Gabinet NM, Portnov BA. Assessing the impacts of ALAN and noise proxies on sleep duration and quality: evidence from a nation-wide survey in Israel. Chronobiol Int. 2021 May;38(5):638–58.

066 Wahl S, Engelhardt M, Schaupp P, Lappe C, Ivanov I V. The inner clock—Blue light sets the human rhythm. J Biophotonics [Internet]. 2019 Dec 2;12(12). Available from: https://www.peeref.com/works/19015015

067 Stevens R. What rising light pollution means for our health - BBC Future. BBC [Internet]. 2016 [cited 2023 Mar 7]; Available from: https://www.bbc.com/future/article/20160617-what-rising-light-pollution-means-for-our-health

068 Vivid Maps. Light Pollution in the United States - Vivid Maps [Internet]. Vivid maps. 2015 [cited 2023 Mar 7]. Available from: https://vividmaps.com/light-pollution-in-us/

069 Let's Talk Science. Light Pollution [Internet]. Lets talk science. 2020 [cited 2023 Mar 7]. Available from: https://letstalkscience.ca/educational-resources/stem-in-context/light-pollution

070 Lau B. What is Light Pollution? | Earth.Org [Internet]. Earth.org. 2021 [cited 2023 Mar 7]. Available from: https://earth.org/what-is-light-pollution/

071 MSIMANG A, VERMAAK M. REVISED MINIMUM EMISSION STANDARDS PROVIDE RELIEF FOR MAJOR SULPHUR DIOXIDE (SO2) EMITTERS [Internet]. BOWMANS The value of knowing. 2020. Available from: https://bowmanslaw.com/insights/environmental-law/revised-minimum-emission-standards-provide-relief-for-major-sulphur-dioxide-so2-emitters/#:~:text=By way of background%2C minimum,ecological conditions or cultural heritage

072 National Institute of General Medical Sciences. Circadian Rhythms [Internet]. Circadian Rhythms. 2022. Available from: https://nigms.nih.gov/education/fact-sheets/Pages/circadian-rhythms.aspx#:~:text=What are circadian,the study of circadian rhythms

073 Philips. How is white light produced by LEDs? [Internet]. Philips - FAQ. 2020. Available from: https://www.lighting.philips.com/main/support/support/faqs/white-light-and-colour/how-is-white-light-produced-by-leds

074 MedlinePlus. Metabolic Disorders [Internet]. Health Topics. 2022. Available from: https://medlineplus.gov/metabolicdisorders.html#:~:text=A metabolic disorder occurs when,are different groups of disorders.

075 National Institute of Environmental Health Sciences. Endocrine Disruptors [Internet]. Health and education. 2023. Available from: https://www.niehs.nih.gov/health/topics/agents/endocrine/index.cfm

076 Soler R. Melanopic Equivalent Daylight Illuminance [Internet]. Human lighting research. 2020. Available from: https://biosinstitute.org/melanopic-equivalent-daylight-illuminance/

077 Kocifaj M. Towards a comprehensive city emission function (CCEF). J Quant Spectrosc Radiat Transf [Internet]. 2018 Jan;205:253–66. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0022407317304776

078 Tricco AC, Langlois E, Straus S. Rapid reviews to strengthen health policy and systems: a practical guide [Internet]. Geneva; 2017. Available from: https://apps.who.int/iris/bitstream/handle/10665/258698/9789241512763-eng.pdf

079 Page MJ, Moher D, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. BMJ [Internet]. 2021 Mar 29;n160. Available from: https://www.bmj.com/lookup/doi/10.1136/bmj.n160

080 Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan—a web and mobile app for systematic reviews. Syst Rev [Internet]. 2016 Dec 5;5(1):210. Available from: http://systematicreviewsjournal.biomedcentral.com/articles/10.1186/s13643-016-0384-4

081 Harris PA, Taylor R, Minor BL, Elliott V, Fernandez M, O'Neal L, et al. The REDCap consortium: Building an international community of software platform partners. J Biomed Inform [Internet]. 2019 Jul;95:103208. Available from: https://linkinghub.elsevier.com/retrieve/pii/S1532046419301261

082 Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)—A metadata-driven methodology and workflow process for providing translational research informatics support. J Biomed Inform [Internet]. 2009 Apr;42(2):377–81. Available from: https://linkinghub.elsevier.com/retrieve/pii/S1532046408001226

083 Hong QN, Fàbregues S, Bartlett G, Boardman F, Cargo M, Dagenais P, et al. The Mixed Methods Appraisal Tool (MMAT) version 2018 for information professionals and researchers. Education for Information [Internet]. 2018 Dec 18;34(4):285–91. Available from: https://www.medra.org/servlet/aliasResolver?alias=iospress&doi=10.3233/EFI-180221

084 Boslett A, Hill E, Ma L, Zhang L. Rural light pollution from shale gas development and associated sleep and subjective well-being. Resour Energy Econ [Internet]. 2021 May;64:101220. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0928765521000051

085 Yasukouchi A, Maeda T, Hara K, Furuune H. Non-visual effects of diurnal exposure to an artificial skylight, including nocturnal melatonin suppression. J Physiol Anthropol [Internet]. 2019 Dec 28;38(1):10. Available from: https://jphysiolanthropol.biomedcentral.com/articles/10.1186/s40101-019-0203-4

086 Rybnikova N, Stevens RG, Gregorio DI, Samociuk H, Portnov BA. Kernel density analysis reveals a halo pattern of breast cancer incidence in Connecticut. Spat Spatiotemporal Epidemiol. 2018 Aug;26:143–51.

087 Stebelova K, Roska J, Zeman M. Impact of Dim Light at Night on Urinary 6-Sulphatoxymelatonin Concentrations and Sleep in Healthy Humans. Int J Mol Sci. 2020 Oct;21(20).

088 Hu K, Li W, Zhang Y, Chen H, Bai C, Yang Z, et al. Association between outdoor artificial light at night and sleep duration among older adults in China: A cross-sectional study. Environ Res. 2022 Sep;212(Pt B):113343.

089 Amdisen L, Daugaard S, Vestergaard JM, Vested A, Bonde JP, Vistisen HT, et al. A longitudinal study of morning, evening, and night light intensities and nocturnal sleep quality in a working population. Chronobiol Int [Internet]. 2022 Apr 3;39(4):579–89. Available from: https://www.tandfonline.com/doi/full/10.1080/07420528.2021.2010741

090 Kim YJ, Park MS, Lee E, Choi JW. High Incidence of Breast Cancer in Light-Polluted Areas with Spatial Effects in Korea. Asian Pacific Journal of Cancer Prevention [Internet]. 2016 Feb 5;17(1):361–7. Available from: http://koreascience.or.kr/journal/view.jsp?kj=POCPA9&py=2016&vnc=v17n1&sp=361

091 Patel PC. Light pollution and insufficient sleep: Evidence from the United States. American Journal of Human Biology [Internet]. 2019 Nov 24;31(6):e23300. Available from: https://onlinelibrary.wiley.com/doi/10.1002/ajhb.23300

092 Clarke RB, Amini H, James P, von Euler-Chelpin M, Jørgensen JT, Mehta A, et al. Outdoor light at night and breast cancer incidence in the Danish Nurse Cohort. Environ Res. 2021 Mar;194:110631.

093 Popay J, Roberts H, Sowden A, Petticrew M, Arai L, Rodgers M, et al. Guidance on the Conduct of Narrative Synthesis in Systematic Reviews A Product from the ESRC Methods [Internet]. 2006 Apr [cited 2023 Mar 7]. Available from: https://www.lancaster.ac.uk/media/lancaster-university/content-assets/documents/fhm/dhr/chir/NSsynthesisguidanceVersion1-April2006.pdf

094 American Medical Association. AMA adopts guidance to reduce harm from high intensity street lights | American Medical Association [Internet]. AMA. 2016 [cited 2023 Mar 7]. Available from: https://www.ama-assn.org/press-center/press-releases/ama-adopts-guidance-reduce-harm-high-intensity-street-lights

095 Argentiero A, Cerqueti R, Maggi M. Outdoor light pollution and COVID-19: The Italian case. Environ Impact Assess Rev [Internet]. 2021 Sep;90:106602. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0195925521000524

096 Bauer SE, Wagner SE, Burch J, Bayakly R, Vena JE. A case-referent study: light at night and breast cancer risk in Georgia. Int J Health Geogr. 2013 Apr;12:23.

097 Bedrosian TA, Nelson RJ. Influence of the modern light environment on mood. Mol Psychiatry. 2013 Jul;18(7):751–7.

098 Bedrosian TA, Fonken LK, Nelson RJ. Endocrine Effects of Circadian Disruption. Annu Rev Physiol. 2016;78:109–31.

099 Bożejko M, Tarski I, Małodobra-Mazur M. Outdoor artificial light at night and human health: A review of epidemiological studies. Environ Res. 2023 Feb;218:115049.

100 Cajochen C, Reichert C, Maire M, Schlangen LJM, Schmidt C, Viola AU, et al. Evidence That Homeostatic Sleep Regulation Depends on Ambient Lighting Conditions during Wakefulness. Clocks Sleep [Internet]. 2019 Dec 11 [cited 2023 Mar 7];1(4):517–31. Available from: https://www.preprints.org/manuscript/201909.0129/v1

101 Chellappa SL. Individual differences in light sensitivity affect sleep and circadian rhythms. Sleep. 2021 Feb;44(2).

102 Cupertino MDC, Guimarães BT, Pimenta JFG, Almeida LVLD, Santana LN, Ribeiro TA, et al. LIGHT POLLUTION: a systematic review about the impacts of artificial light on human health. Biol Rhythm Res [Internet]. 2023 Mar 4;54(3):263–75. Available from: https://www.tandfonline.com/doi/full/10.1080/09291016.2022.2151763

103 Davies TW, Smyth T. Why artificial light at night should be a focus for global change research in the 21st century. Glob Chang Biol. 2018;24(3):872–82.

104 Conscience E. 27 Causes, Effects & Solutions for Light Pollution - E&C. Environmental Conscience [Internet]. Available from: https://environmental-conscience.com/causes-effects-solutions-for-light-pollution/

105 Fleury G, Masís-Vargas A, Kalsbeek A. Metabolic Implications of Exposure to Light at Night: Lessons

from Animal and Human Studies. Obesity (Silver Spring). 2020 Jul;28 Suppl 1(Suppl 1):S18–28.

106 Green A, Cohen-Zion M, Haim A, Dagan Y. Evening light exposure to computer screens disrupts human sleep, biological rhythms, and attention abilities. Chronobiol Int. 2017;34(7):855–65.

107 Haim A, Zubidat AE. Artificial light at night: melatonin as a mediator between the environment and epigenome. Philos Trans R Soc Lond B Biol Sci. 2015 May;370(1667).

108 Harb F, Hidalgo MP, Martau B. Lack of exposure to natural light in the workspace is associated with physiological, sleep and depressive symptoms. Chronobiol Int. 2015 Apr;32(3):368–75.

109 Harmsen JF, Wefers J, Doligkeit D, Schlangen L, Dautzenberg B, Rense P, et al. The influence of bright and dim light on substrate metabolism, energy expenditure and thermoregulation in insulin-resistant individuals depends on time of day. Diabetologia [Internet]. 2022 Apr 2;65(4):721–32. Available from: https://link.springer.com/10.1007/s00125-021-05643-9

110 Hartmann M, Pelzl MA, Kann PH, Koehler U, Betz M, Hildebrandt O, et al. The effects of prolonged single night session of videogaming on sleep and declarative memory. Triberti S, editor. PLoS One [Internet]. 2019 Nov 21;14(11):e0224893. Available from: https://dx.plos.org/10.1371/journal.pone.0224893

111 International Dark-Sky Association. Human Health - International Dark-Sky Association [Internet]. International Dark-Sky Association. [cited 2023 Mar 6]. Available from: https://www.darksky.org/light-pollution/human-health/

112 Jin X, Li Y, Zhang J, Zheng J, Liu H. An Approach to Evaluating Light Pollution in Residential Zones: A Case Study of Beijing. Sustainability [Internet]. 2017 Apr 19;9(4):652. Available from: http://www.mdpi.com/2071-1050/9/4/652

113 Keshet-Sitton A, Or-Chen K, Yitzhak S, Tzabary I, Haim A. Can Avoiding Light at Night Reduce the Risk of Breast Cancer? Integr Cancer Ther. 2016 Jun;15(2):145–52.

114 Kozaki T, Kubokawa A, Taketomi R, Hatae K. Effects of day-time exposure to different light intensities on light-induced melatonin suppression at night. J Physiol Anthropol. 2015 Jul;34(1):27.

115 LE TALLEC T. What is the ecological impact of light pollution? - Encyclopedia of the Environment [Internet]. 2019 [cited 2023 Mar 7]. Available from: https://www.encyclopedie-environnement.org/en/life/what-is-the-ecological-impact-of-light-pollution/

116 Leger D, Guilleminault C. Environmental open-source data sets and sleep-wake rhythms of populations: an overview. Sleep Med [Internet]. 2020 May;69:88–97. Available from: https://linkinghub.elsevier.com/retrieve/pii/S1389945720300149

117 Lin LZ, Zeng XW, Deb B, Tabet M, Xu SL, Wu QZ, et al. Outdoor light at night, overweight, and obesity in school-aged children and adolescents. Environmental Pollution [Internet]. 2022 Jul;305:119306. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0269749122005206

118 Lok R, Woelders T, Gordijn MCM, Hut RA, Beersma DGM. White Light During Daytime Does Not Improve Alertness in Well-rested Individuals. J Biol Rhythms [Internet]. 2018 Dec 7;33(6):637–48. Available from: http://journals.sagepub.com/doi/10.1177/0748730418796036

119 Lunn RM, Blask DE, Coogan AN, Figueiro MG, Gorman MR, Hall JE, et al. Health consequences of electric lighting practices in the modern world: A report on the National Toxicology Program's workshop on shift work at night, artificial light at night, and circadian disruption. Sci Total Environ. 2017 Dec;607–608:1073–84.

120 Maggio R, Vaglini F, Rossi M, Fasciani I, Pietrantoni I, Marampon F, et al. Parkinson's disease and light: The bright and the Dark sides. Brain Res Bull [Internet]. 2019 Aug;150:290–6. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0361923019302461

121 An M, Colarelli SM, O'Brien K, Boyajian ME. Why We Need More Nature at Work: Effects of Natural Elements and Sunlight on Employee Mental Health and Work Attitudes. Branchi I, editor. PLoS One [Internet]. 2016 May 23 [cited 2023 Mar 7];11(5):e0155614. Available from: https://easy.dans.knaw.nl/ui/datasets/id/easy-dataset:92934

122 Ng CM, Kaur S. Environmental light exposure and mealtime regularity: Implications for human health. Chronobiol Int. 2022 Sep;39(9):1183–94.

123 Ngarambe J, Lim HS, Kim G. Light pollution: Is there an Environmental Kuznets Curve? Sustain Cities Soc [Internet]. 2018 Oct;42:337–43. Available from: https://linkinghub.elsevier.com/retrieve/pii/

S2210670717315317

124 Oldham MA, Lee HB, Desan PH. Circadian Rhythm Disruption in the Critically Ill: An Opportunity for Improving Outcomes. Crit Care Med. 2016 Jan;44(1):207–17.

125 Peña-García A, Sędziwy A. Optimizing lighting of rural roads and protected areas with white light: A compromise among light pollution, energy savings, and visibility. Leukos. 2020;16(2):147–56.

126 Pérez Vega C, Zielinska-Dabkowska KM, Hölker F. Urban Lighting Research Transdisciplinary Framework—A Collaborative Process with Lighting Professionals. Int J Environ Res Public Health [Internet]. 2021 Jan 13;18(2):624. Available from: https://www.mdpi.com/1660-4601/18/2/624

127 Pothukuchi K. City Light or Star Bright: A Review of Urban Light Pollution, Impacts, and Planning Implications. J Plan Lit [Internet]. 2021 May 21;36(2):155–69. Available from: http://journals.sagepub.com/doi/10.1177/0885412220986421

128 Rajput S, Naithani M, Meena K, Rana S. Light pollution: hidden perils in light and links to cancer. Sleep Vigil. 2021;5(1):5–16.

129 Randjelović P, Stojanović N, Ilić I, Vučković D. The effect of reducing blue light from smartphone screen on subjective quality of sleep among students. Chronobiol Int. 2023 Feb;1–8.

130 Rybnikova N, Haim A, Portnov BA. Artificial Light at Night (ALAN) and breast cancer incidence worldwide: A revisit of earlier findings with analysis of current trends. Chronobiol Int [Internet]. 2015 Jul 3;32(6):757–73. Available from: http://www.tandfonline.com/doi/full/10.3109/07420528.2015.1043369

131 Samson DR, Manus MB, Krystal AD, Fakir E, Yu JJ, Nunn CL. Segmented sleep in a nonelectric, small-scale agricultural society in Madagascar. American Journal of Human Biology [Internet]. 2017 Feb;29(4):e22979. Available from: https://onlinelibrary.wiley.com/doi/10.1002/ajhb.22979

132 Smolensky MH, Sackett-Lundeen LL, Portaluppi F. Nocturnal light pollution and underexposure to daytime sunlight: Complementary mechanisms of circadian disruption and related diseases. Chronobiol Int [Internet]. 2015 Sep 14;32(8):1029–48. Available from: http://www.tandfonline.com/doi/full/10.3109/07420528.2015.1072002

133 Stebelova K, Kosnacova J, Zeman M. Intense blue light therapy during the night-time does not suppress the rhythmic melatonin biosynthesis in a young boy. Endocr Regul. 2017 Jan;51(1):31–4.

134 Tancredi S, Urbano T, Vinceti M, Filippini T. Artificial light at night and risk of mental disorders: A systematic review. SCIENCE OF THE TOTAL ENVIRONMENT. 2022;833.

135 Tavares P, Ingi D, Araújo L, Pinho P, Bhusal P. Reviewing the Role of Outdoor Lighting in Achieving Sustainable Development Goals. Sustainability [Internet]. 2021 Nov 16;13(22):12657. Available from: https://www.mdpi.com/2071-1050/13/22/12657

136 Touitou Y, Reinberg A, Touitou D. Association between light at night, melatonin secretion, sleep deprivation, and the internal clock: Health impacts and mechanisms of circadian disruption. Life Sci. 2017 Mar;173:94–106.

137 Walker WH 2nd, Walton JC, DeVries AC, Nelson RJ. Circadian rhythm disruption and mental health. Transl Psychiatry. 2020 Jan;10(1):28.

138 Wieduwilt A, Alsat EA, Blickwedel J, Strizek B, Di Battista C, Lachner AB, et al. Dramatically altered environmental lighting conditions in women with high-risk pregnancy during hospitalization. Chronobiol Int [Internet]. 2020 Aug 2;37(8):1201–6. Available from: https://www.tandfonline.com/doi/full/10.1080/07420528.2020.1792484

139 Yang WS, Deng Q, Fan WY, Wang WY, Wang X. Light exposure at night, sleep duration, melatonin, and breast cancer. European Journal of Cancer Prevention [Internet]. 2014 Jul;23(4):269–76. Available from: https://journals.lww.com/00008469-201407000-00006

140 Kim KY, Lee E, Kim YJ, Kim J. The association between artificial light at night and prostate cancer in Gwangju City and South Jeolla Province of South Korea. Chronobiol Int. 2017;34(2):203–11.

141 Zielinska-Dabkowska KM. Healthier and Environmentally Responsible Sustainable Cities and Communities. A New Design Framework and Planning Approach for Urban Illumination. Sustainability [Internet]. 2022 Nov 4;14(21):14525. Available from: https://www.mdpi.com/2071-1050/14/21/14525

APPENDIX 1: DESIGN

The review followed established guidelines for the conduct of evidence reviews developed by Tricco, Langlois and Straus (2017), [5] with the scope to incorporate relevant grey literature. We also followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement to guide the review design and the reporting of the methods and findings [6].

SEARCH STRATEGY

Search terms were developed based on example literature and refined and agreed on by key stakeholders. The search strategy was tested across databases to develop the final search strategy. We searched four peer-reviewed literature databases (PubMed, MEDLINE, Web of Science, and PsycInfo) for literature published between January 2013 and April 2023, and six databases for grey literature and policy documents (Policy Commons, Social Science Database, Google Scholar, Dogpile, OSF preprints, and Opengrey). Searches were conducted on the 6th of March 2023. Details of the search terms and databases are provided in Appendix 1.

ELIGIBILITY CRITERIA

Published and grey literature of any type were included if they met the following criteria:

- Published in the last ten years (January 2013- April 2023)
- Describe one of the following:
  - ◊ The influence of artificial light on (physical or mental) health
  - ◊ The role of national and local authorities in combatting the effects
  - ◊ Possible interventions to control or mitigate the effects

SCREENING PROCESS AND DOCUMENT SELECTION

Search results were imported into Rayyan, an online software tool for team-based screening and article selection [7]. Two researchers screened records at the title and abstract level according to the eligibility criteria and cross-checked 25% of each other's exclusions. Finally, two researchers reviewed full-text versions independently. Discrepancies were resolved via discussion and disagreements were managed by the research lead.

DATA EXTRACTION

Relevant data from each included item were extracted into a form by one of three researchers developed using REDCap [8,9]. REDCap is a secure, web-based software platform designed specifically to support data capture of research studies. The information extracted included author, publication year, country, study design/ type of article, relevant information regarding the study population, type of light exposure, and information relating to our research questions, namely:

1) Mechanisms of light pollution impacting human health
2) Negative effects of light pollution
3) Primary sources of light pollution
4) Most harmful sources of light pollution
5) Details of worsening of light pollution
6) Interventions to mitigate the effects of light pollution
7) Details of global, national, or local authority roles in addressing light pollution

QUALITY ASSESSMENT

The Mixed Methods Appraisal Tool (MMAT) [10] was used to assess the quality of research articles. Qualitative, quantitative, and mixed methods research designs can all be appraised using the MMAT. Each study was given a score based on a scale of zero to five considering the number of positive or negative points on the five appraisals(related to the design of the study). After assessing the included articles with the MMAT tool, the average score was 3.62.

Overall, there are various methodological limitations and shortcomings. These include inadequate sample sizes

(84), insufficient control of confounding factors (13,85–87), reliance on self-reported measures (65,84,88,89), and incomplete follow-up data (21). Some studies also fail to control for relevant factors such as ethnicity and socio-economic status (41,49,90–92). In some cases, data collection methods are called into question, such as the use of proxy measures for light pollution or the lack of accuracy in the use of single-point photos to measure light (13,62).

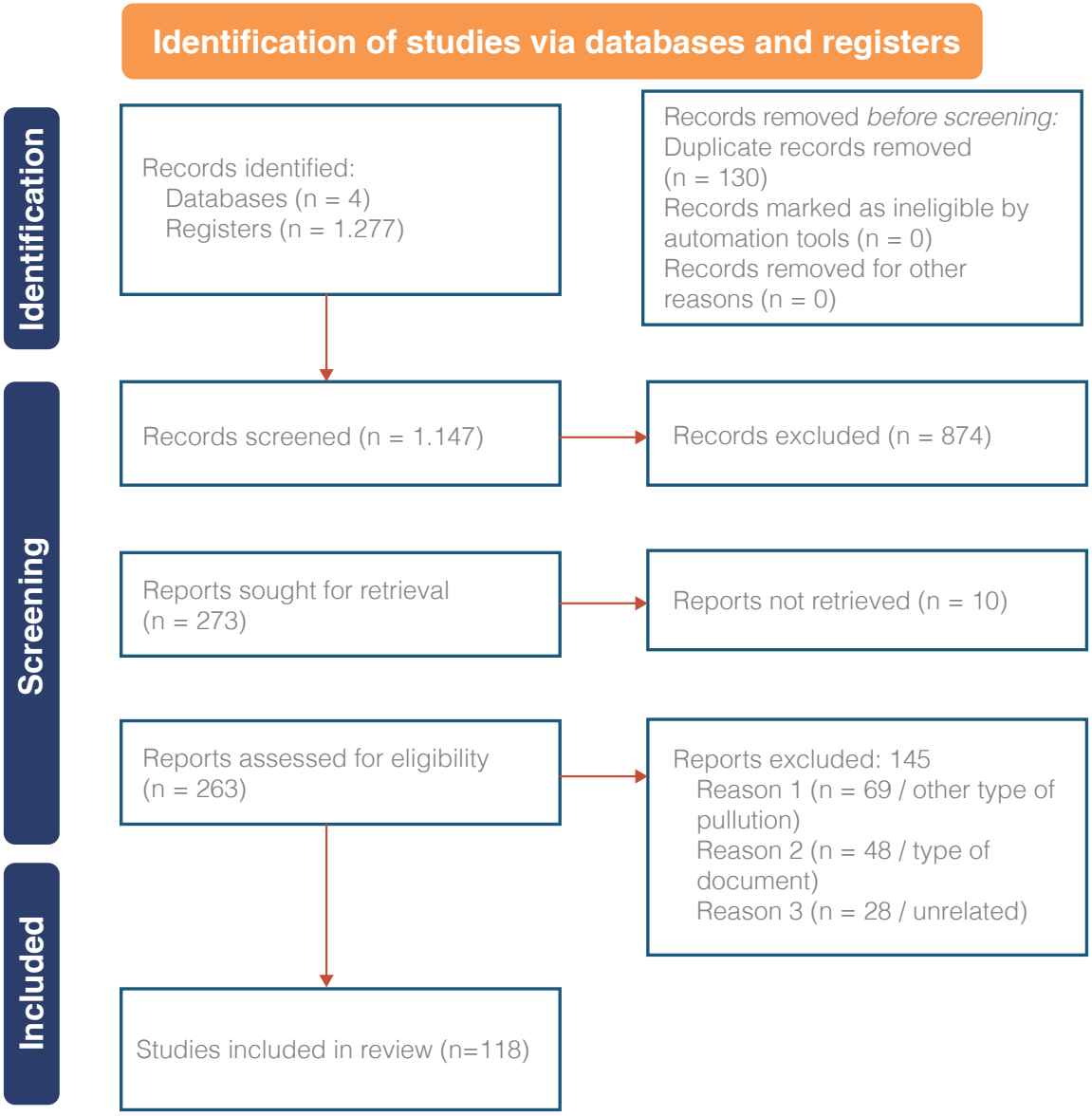
DATA SYNTHESIS

The data were narratively synthesised following established guidance by Popay and colleagues [11]. Data relevant to each research question was summarised together, with key similarities and differences between included literature highlighted.

APPENDIX 2: RESULTS

In total we identified 1147 information sources of published and grey literature. Title and abstract screening resulted in the exclusion of 1029 sources, leaving 118 studies and reports included. The main exclusion reasons were the type of pollution, type of document, and relatedness to the topic. A full description of the flow of studies through the screening process is shown in Figure 1, including reasons for exclusion.

Figure 1: PRISMA Diagram



STUDY CHARACTERISTICS

Of the 118 included sources, 35 did not specify a country, 21 were based on global information, and one was based on European information. The remaining studies were most commonly from the USA (n=13), followed by South Korea (n=7), Israel (n=6) and China (n=5). Most studies were published in and after 2020 (n=60), with 40 published between 2016 and 2019, and the remaining 18 published in 2013 or 2014. While 61 of the included sources were non-empirical (i.e., reviews, commentaries, and editorials), 55 were quantitative studies and one was a mixed methods design. Two sources described the effects of natural light only, 9 sources described the effects of both natural and artificial light and the remaining 107 described the effects of artificial light only. Further details of the characteristics of each included study are available in Table 1.

APPENDIX 3: ADDITIONAL RELEVANT LITERATURE IDENTIFIED BY EXPERT STAKEHOLDERS:

- Zissis, G., Bertoldi, P., Serrenho T. Update on the Status of LED-Lighting world market since 2018, EUR 30500 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-27244-1, doi:10.2760/759859, JRC122760 2018. https://doi.org/10.2760/759859.
- International Energy Agency (IGA). Global lighting sales in the Net Zero Scenario, 2010-2030 – Charts – Data & Statistics - IEA 2022. https://www.iea.org/data-and-statistics/charts/global-lighting-sales-in-the-net-zero-scenario-2010-2030 (accessed May 11, 2023).
- Kyba CCM, Altıntaş YÖ, Walker CE, Newhouse M. Citizen scientists report global rapid reductions in the visibility of stars from 2011 to 2022. Science (1979) 2023;379:265–8. https://doi.org/10.1126/SCIENCE.ABQ7781/SUPPL_FILE/SCIENCE.ABQ7781_SM.V1.PDF.
- de Miguel AS, Bennie J, Rosenfeld E, Dzurjak S, Gaston KJ. First estimation of global trends in nocturnal power emissions reveals acceleration of light pollution. Remote Sens (Basel) 2021;13:3311. https://doi.org/10.3390/RS13163311/S1.
- Sweeney MR, Nichols HB, Jones RR, Olshan AF, Keil AP, Engel LS, et al. Light at night and the risk of breast cancer: Findings from the Sister study. Environ Int 2022;169:107495. https://doi.org/10.1016/J.ENVINT.2022.107495.
- Kocifaj M, Barentine JC. Air pollution mitigation can reduce the brightness of the night sky in and near cities. Scientific Reports 2021 11:1 2021;11:1–10. https://doi.org/10.1038/s41598-021-94241-1.
- Shith S, Ramli NA, Awang NR, Ismail MR, Latif MT, Zainordin NS. Does Light Pollution Affect Nighttime Ground-Level Ozone Concentrations? Atmosphere 2022, Vol 13, Page 1844 2022;13:1844. https://doi.org/10.3390/ATMOS13111844.
- Kennaway DJ. Melatonin rich foods in our diet: food for thought or wishful thinking? Food Funct [Internet]. 2020;11(11):9359–69. Available from: http://xlink.rsc.org/?DOI=D0FO02563A
- Foster RG, Hughes S, Peirson SN. Circadian Photoentrainment in Mice and Humans. Biology (Basel) [Internet]. 2020 Jul 21;9(7):180. Available from: https://www.mdpi.com/2079-7737/9/7/180
- Foster RG. Sleep, circadian rhythms and health. Interface Focus [Internet]. 2020 Jun 6;10(3):20190098. Available from: https://royalsocietypublishing.org/doi/10.1098/rsfs.2019.0098
- Foster RG. Light Regulation of Circadian Rhythms: Fact and Fiction and Design Implications. Archit Des [Internet]. 2020 Nov 2;90(6):66–71. Available from: https://onlinelibrary.wiley.com/doi/10.1002/ad.2633
- Foster RG. Melatonin. Curr Biol [Internet]. 2021 Nov;31(22):R1456–8. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0960982221014184

APPENDIX 4: SEARCH STRATEGY

THEMES

#1 LIGHT

light OR glare OR skyglow OR light trespass OR clutter OR ALAN OR anthropogenic light OR dim light OR light at night OR artificial blue light

#2 POLLUTION

light pollution OR pollution OR urbani#ation OR light pollution OR Artificial light at night

#3 HUMAN

human OR human health) AND (circadian rhythm* OR sleep architecture OR sleep quality OR circadian time structure OR sleep/wake cycle disturbance OR quality of life OR melatonin OR clock genes)

#4 IMPACT ON HEALTH

health effects OR health influence OR health damage OR lighting effects OR lighting adverse effects OR sleep effects OR radiation effects OR circadian rhythm effects OR radiation effects OR environmental exposure

STRATEGY

For the exploration of results to determine sensitivity versus breadth, we used 1 + 2 + 3 + 4

(light OR glare OR skyglow OR light trespass OR clutter OR ALAN OR anthropogenic light OR dim light OR light at night OR artificial blue light) AND (light pollution OR pollution OR urbani#ation OR light pollution OR Artificial light at night) AND (Human OR human health) AND (circadian rhythm* OR sleep architecture OR sleep quality OR circadian time structure OR sleep cycle disturbance OR wake cycle disturbance OR quality of life OR melatonin OR clock genes) AND (health effects OR health influence OR health damage OR lighting effects OR lighting adverse effects OR sleep effects OR radiation effects OR circadian rhythm effects OR radiation effects OR environmental exposure)

Table 1 – Main characteristics of included records

AUTHOR, YEAR	COUNTRY (SPECIFIC LOCATION IF REPORTED)	PUBLICATION TYPE	STUDY DESIGN (IF QUANTITATIVE STUDY)	POPULATION OF INTEREST	TYPE OF LIGHT
Amdisen, 2021 / [12]	Denmark	Quantitative study	Survey		Artificial light
American Medical Association, 2016 / [13]	USA	Non-empirical report (i.e., review, commentary)			Artificial light
Arcadia, 2017 / [14]	Not specified	Non-empirical report (i.e., review, commentary)			Artificial light
Argentiero, 2021 / [15]	Italy	Quantitative study	descriptive, cross-sectional	People diagnosed with Covid 19	Artificial light
Bauer, 2013 / [16]	Georgia	Quantitative study	Case-Control		Artificial light
Bedrosian, 2013 / [17]	Not specified	Non-empirical report (i.e., review, commentary)			Artificial light

Bedrosian, 2016 / [18]	Not specified	Non-empirical report (i.e., review, commentary)			Artificial light
Bjelajac, 2019 / [19]	Serbia	Non-empirical report (i.e., review, commentary)			Artificial light
Blume, 2019 / [20]	Not specified	Non-empirical report (i.e., review, commentary)			Both natural and artificial light
Boslett, 2021 / [21]	USA	Quantitative study	cross-sectional		Artificial light
Bożejko, 2023 / [22]	Worldwide	Non-empirical report (i.e., review, commentary)			Artificial light
Brown, 2022 / [23]	Worldwide	Non-empirical report (i.e., review, commentary)			Artificial light
Cajochen, 2019 / [24]	Switzerland	Quantitative study	controlled trial	younger vs older individuals	Artificial light
Cao, 2022 / [25]	Not specified	Non-empirical report (i.e., review, commentary)			Artificial light
Carta, 2018 / [26]	Not specified	Non-empirical report (i.e., review, commentary)		People with bipolar disorders	Artificial light
Chellappa, 2021 / [27]	Not specified	Non-empirical report (i.e., review, commentary)			Artificial light
Cho, 2013 / [28]	South Korea	Quantitative study	cross-sectional		Artificial light
Cho, 2015 / [29]	Worldwide	Non-empirical report (i.e., review, commentary)			Artificial light
Cho, 2016 / [30]	South Korea (Korea University Anam Hospital)	Quantitative study	Randomised controlled trial	Male university students	Artificial light
Clarke, 2021 / [31]	Denmark	Quantitative study	Cohort study	Nurses	Both natural and artificial light
Coogan, 2020 / [32]	Ireland	Quantitative study	cross-sectional survey		Artificial light
Cote-Lussier, 2020 / [33]	Canada (Quebec)	Quantitative study	Cross-sectional	Children aged 8-10	Artificial light
Cupertino, 2022 / [34]	Not specified	Non-empirical report (i.e., review, commentary)	Systematic review		Artificial light
Davies, 2018 / [35]	Not specified	Non-empirical report (i.e., review, commentary)			Artificial light

Dutfield, 2022 / [36]	Worldwide	Non-empirical report (i.e., review, commentary)			Artificial light
Environmental Conscience, 2023 / [37]	Not specified	Non-empirical report (i.e., review, commentary)			Artificial light
Falchi, 2019 / [4]	USA	Non-empirical report (i.e., review, commentary)			Artificial light
Filmer, 2013 / [38]	Not specified	Non-empirical report (i.e., review, commentary)			Artificial light
Fleury, 2020 / [39]	Not specified	Non-empirical report (i.e., review, commentary)			Artificial light
Gabinet, 2021 / [40]	Israel	Quantitative study	Survey		Artificial light
Garcia-Saenz, 2018 / [41]	Spain	Quantitative study	Case-control		Artificial light
Green, 2017 / [42]	Israel (Tel Aviv)	Quantitative study	Non-randomized crossover design		Artificial light
Green, 2018 / [43]	Israel	Quantitative study	cross-sectional		Artificial light
Grose, 2014 / [44]	Australia (Melbourne)	Non-empirical report (i.e., review, commentary)			Artificial light
Haim, 2015 / [45]	Not specified	Non-empirical report (i.e., review, commentary)			Artificial light
Harb, 2015 / [46]	Brazil (Porto Alegre)	Quantitative study	Cross-sectional		Natural light
Harmsen, 2022 / [47]	Netherlands (Maastricht)	Quantitative study	Randomised crossover trial	Male and female, overweight, insulin-resistant volunteers	Artificial light
Hartmann, 2019 / [48]	Germany (Marburg)	Quantitative study	cross-sectional	adolescent males	Artificial light
Hu, 2022 / (88)	China	Quantitative study	Cross-sectional	Older adults (>65 years) in China	Artificial light
International Dark Sky Association, 2023 / (111)	Not specified	Non-empirical report (i.e., review, commentary)			Artificial light
Jeong Kim, 2016 / (90)	South Korea (Jeollanam-do province and the adjacent Gwangju metropolitan city)	Quantitative study	Ecological study	People with breast cancer.	Artificial light

Jin, 2017 / (112)	China (Beijing)	Quantitative study	Case study of light pollution assessment method		Both natural and artificial light
John C. Wells Planetarium, 2013 / (45)	USA	Non-empirical report (i.e., review, commentary)			Artificial light
Keshet-Sitton, 2017 / (48)	Israel (Ahkelon)	Quantitative study	Correlational analysis	Women aged 35-74 with new Breast Cancer cases between 2004 and 2012.	Artificial light
Keshet-Sitton, 2017 / (13)	Israel	Quantitative study	descriptive, cross-sectional	Breast cancer patients	Artificial light
Keshet-Stitton, 2016 / (113)	Israel	Quantitative study	Case-control		Artificial light
Kim, 2016 / (90)	South Korea (South-west, Jeollanam-do province and the adjacent Gwangju metropolitan city.)	Quantitative study	Retrospective cohort		Artificial light
Kozaki, 2015 / (114)	Japan	Quantitative study	Experimental / Times series		Artificial light
Kumar, 2019 / (10)	Worldwide	Non-empirical report (i.e., review, commentary)			Artificial light
Lahiri, 2020 / (37)	India (West Bengal)	Quantitative study	Cross-sectional		Artificial light
Lai, 2021 / (29)	Worldwide	Non-empirical report (i.e., review, commentary)		people with breast cancer	Artificial light
Lamphar, 2022 / (44)	Slovakia	Quantitative study	Statistical analysis	Women	Artificial light
Lau, 2021 / (70)	Not specified	Non-empirical report (i.e., review, commentary)			Artificial light
Le Tallec, 2019 / (115)	Not specified	Non-empirical report (i.e., review, commentary)			Artificial light
Leger, 2020 / (116)	Worldwide	Non-empirical report (i.e., review, commentary)			Artificial light
Let's talk science, 2020 / (69)	Not specified	Non-empirical report (i.e., review, commentary)			Artificial light
Lin, 2022 / (117)	China (Liaoning Province, Northeast China)	Quantitative study	Cross-sectional survey	Children and adolescents	Artificial light

Lok, 2018 / (118)	The Netherlands (Groningen)	Quantitative study	experimental (unclear if randomised)		Artificial light
Lunn, 2017 / (119)	Not specified	Non-empirical report (i.e., review, commentary)			Artificial light
Maggio, 2019 / (120)	Worldwide	Non-empirical report (i.e., review, commentary)			Both natural and artificial light
Melendez-Fernandez, 2023 / (54)	Not specified	Non-empirical report (i.e., review, commentary)			Artificial light
Mihyang, 2016 / (121)	USA and India	Quantitative study	descriptive, cross-sectional		Natural light
Min, 2018 / (21)	South Korea	Quantitative study	Cross-sectional survey		Artificial light
Ming Ng, 2022 / (122)	Not specified	Non-empirical report (i.e., review, commentary)			Both natural and artificial light
Moralia, 2022 / (57)	Worldwide	Non-empirical report (i.e., review, commentary)		shift workers	Artificial light
Munzel, 2021 / (55)	Not specified	Non-empirical report (i.e., review, commentary)			Artificial light
Muscogiuri, 2022 / (32)	Worldwide	Non-empirical report (i.e., review, commentary)			Artificial light
National Geographic, 2022 / (27)	Not specified	Non-empirical report (i.e., review, commentary)			Artificial light
Ngarambe, 2018 / (123)	South Korea (Gyeonggi province)	Quantitative study	Ecological study		Both natural and artificial light
Nguyen, 2019 / (34)	Thailand (Surin Province)	Quantitative study	cross-sectional	Vendors and non-vendors attending night markets	Artificial light
Obayashi, 2019 / (56)	Japan	Quantitative study	Prospective cohort	Elderly	Artificial light
Oldham, 2015 / (124)	Not specified	Non-empirical report (i.e., review, commentary)		Critically ill people	Both natural and artificial light
Paksarian, 2020 / (43)	USA	Mixed methods	Statistical analysis and interviews	Adolescents	Artificial light
Pandey, 2013 / (11)	Not specified	Non-empirical report (i.e., review, commentary)			Artificial light

Patel, 2019 / (91)	USA	Quantitative study	Correlational analysis	Adults with sleep problems	Artificial light
Peña, 2019 / (125)	Not specified	Quantitative study	Non-randomized trial	Rural roads and protected areas	Artificial light
Pérez Vega, 2021 / (126)	Not specified	Non-empirical report (i.e., review, commentary)			Artificial light
Pothukuchi, 2021 / (127)	Not specified	Non-empirical report (i.e., review, commentary)			Artificial light
Rajkhowa, 2014 / (12)	Not specified	Non-empirical report (i.e., review, commentary)			Artificial light
Rajput, 2021 / (128)	Not specified	Non-empirical report (i.e., review, commentary)			Artificial light
Randjelović, 2023 / (129)	Serbia (University of Nis)	Quantitative study	prospective cohort	Medical students	Artificial light
Robb-Dover, 2020 / (40)	Not specified	Non-empirical report (i.e., review, commentary)			Artificial light
Rybnikova, 2015 / (130)	Worldwide	Quantitative study	cross-sectional	Women with breast cancer	Artificial light
Rybnikova, 2016 / (16)	Worldwide	Quantitative study	retrospective cohort	Adults classified as overweight and obese	Artificial light
Rybnikova, 2018 / (15)	Israel (Haifa Bay Area)	Quantitative study	Ecological study	Women	Artificial light
Samson, 2016 / (131)	Madagascar (Mandena)	Quantitative study	Non-randomised crossover trial		Artificial light
Sánchez de Miguel, 2022 / (61)	Europe	Quantitative study	Data analysis and estimations		Artificial light
Smolensky, 2015 / (132)	Not specified	Non-empirical report (i.e., review, commentary)			Artificial light
Stebelova, 2017 / (133)	Slovakia (Bratislava)	Quantitative study	Case study		Artificial light
Stebelova, 2020 / (87)	Slovakia (Bratislava)	Quantitative study	Single-arm experimental study		Artificial light
Stevens, 2015 / (51)	Worldwide	Non-empirical report (i.e., review, commentary)			Artificial light
Stevens, 2016 / (67)	Worldwide	Non-empirical report (i.e., review, commentary)			Artificial light

Suni, 2023 / (19)	Not specified	Non-empirical report (i.e., review, commentary)			Both natural and artificial light
Tancredi, 2022 / (134)	Worldwide	Non-empirical report (i.e., review, commentary)		Humans with mental disorders	Artificial light
Tavares, 2021 / (135)	Not specified	Non-empirical report (i.e., review, commentary)			Both natural and artificial light
Tonon, 2022 / (41)	Brazil (Porto Alegre)	Quantitative study	Cohort study	Adolescents aged 14-16	Artificial light
Touitou, 2017 / (136)	Worldwide	Non-empirical report (i.e., review, commentary)			Artificial light
Touitou, 2020 / (63)	Worldwide	Non-empirical report (i.e., review, commentary)		Young people between the ages of 10 and 19 years	Artificial light
Vivid maps, 2023 / (68)	USA	Non-empirical report (i.e., review, commentary)			Artificial light
Wahl, 2019 / (66)	Worldwide	Non-empirical report (i.e., review, commentary)			Artificial light
Walker II, 2020 / (137)	Not specified	Non-empirical report (i.e., review, commentary)			Artificial light
Walker, 2020 / (47)	Not specified	Non-empirical report (i.e., review, commentary)			Artificial light
Wang, 2022 / (36)	China (Guangdong province in southern China, Liaoning province in north-eastern China, and Xinjiang Uygur Autonomous Region in north-western China)	Quantitative study	Cross-sectional	Children with sleep disorders in China	Artificial light
Wang, 2023 / (35)	Japan	Non-empirical report (i.e., review, commentary)			Artificial light
Weule, 2020 / (26)	Australia	Non-empirical report (i.e., review, commentary)			Artificial light
Wieduwilt, 2020 / (138)	Germany (Bonn)	Quantitative study	Observational study	Pregnant individuals	Artificial light

Xiao, 2020 / (25)	United States (Six states (California, Florida, Louisiana, New Jersey, North Carolina, and Pennsylvania) and two metropolitan areas (Atlanta, Georgia, and Detroit, Michigan))	Quantitative study	Questionnaires		Artificial light
Xiao, 2021 / (24)	USA (six U.S. states (CA, FL, LA, NJ, NC, and PA) and two metropolitan areas (Atlanta, GA and Detroit, MI).)	Quantitative study	retrospective cohort	People who developed Pancreatic ductal adenocarcinoma (PDAC) over the course of the study	Artificial light
Xu, 2022 / (33)	China (Hefei (Anhui Province))	Quantitative study	Cohort study	Young adults (age range, 16-22 years)	Artificial light
Xu, 2023 / (17)	Worldwide	Non-empirical report (i.e., review, commentary)	Systematic review		Artificial light
Yang, 2014 / (139)	Worldwide	Non-empirical report (i.e., review, commentary)			Artificial light
Yasukouchi, 2019 / (85)	Japan (Fukuoka)	Quantitative study	Not clear-cohort		Artificial light
Young Kim, 2016 / (140)	South Korea (Gwangju City and South Jeolla Province)	Quantitative study	Ecological study	Men with prostate cancer	Artificial light
Zhang, 2020 / (31)	USA (six US states (California, Florida, Louisiana, New Jersey, North Carolina, and Pennsylvania) and two metropolitan areas (Atlanta in Georgia and Detroit in Michigan))	Quantitative study	retrospective cohort	Adults from the NIH-AARP Diet and Health Study who were not obese at baseline	Artificial light
Zhang, 2021 / (30)	USA (6 US states (California, Florida, Louisiana, New Jersey, North Carolina, and Pennsylvania) and 2 metropolitan areas (Atlanta, Georgia, and Detroit, Michigan))	Quantitative study	Cross-sectional	People with Thyroid cancer	Artificial light
Zhong, 2020 / (52)	USA (California)	Quantitative study	Prospective cohort		Artificial light
Zhong, 2023 / (53)	USA (California)	Quantitative study	Case-Control	Children	Artificial light
Zielinska-Dabkowska, 2022 / (141)	Worldwide	Non-empirical report (i.e., review, commentary)			Artificial light