

# Artificial light at night and night-shift work: Emerging threats for human health

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Light at night (LAN) is a pervasive environmental alteration that results from the increasing use of artificial lighting during the night-time hours. According to the New World Atlas of Artificial Sky Brightness more than 80% of the world and more than 99% of the US and European populations live under skies polluted by artificial lighting<sup>1</sup>. Many sources of LAN can be identified, including building exterior lighting and streetlights, while exposure to indoor LAN mainly comes from the increasing use of electronic devices and light bulbs. Beside the adverse effects of LAN on wildlife and ecosystems (particularly on behavior, reproduction, and survival of many species)<sup>2-4</sup>, recent evidence from epidemiologic studies suggests that LAN may increase risk of various diseases, such as obesity, diabetes, cardiovascular disease, cancer, as well as mental disorders and sleep disturbances in human<sup>5-8</sup>. In 2021, the US National Toxicology Program (NTP) cancer hazard assessment concluded with sufficient evidence that LAN exposure is related to human cancer<sup>9</sup>. Indeed, LAN may act through different mechanisms of circadian disruption and its biological effects are identified in those of some recognized carcinogens<sup>9</sup>. Mechanisms underlying LAN toxicity include disruption of circadian rhythm, inhibition of melatonin secretion, sleep deprivation and epigenetic modifications of clock genes<sup>10-13</sup>.

In epidemiological studies, LAN exposure can be investigated through different methods. Outdoor LAN (measured in units of nW/cm<sup>2</sup>/sr; nano watts per unit area per steradian) is generally assessed using satellite-based data<sup>14,15</sup>, the most used being those from the US Defense Meteorological Satellite Program (DMSP) Operational

Linescan System or from the Visible Infrared Imaging Radiometer Suite Day-Night Band (DNB)<sup>16,17</sup>. Studies assessing indoor LAN usually report exposure through self-reported questionnaires in which LAN levels are classified in different categories (e.g. low, medium or high) by subjects. Some studies also report information on darkness and nightlight levels, and nocturnal habits such as waking up and turning on lights during night, sleeping with the TV on or off, darkness level perceived in the room, residency near strong artificial LAN sources, wearing a mask or keeping lights on/off while sleeping<sup>18-20</sup>. Indoor LAN can also be assessed with bedroom photometers fixed near the head of the bed or portable ones placed on a participant's wrist<sup>21</sup>.

LAN may exert stronger adverse effects in particular vulnerable subgroups. For instance, some experimental studies have demonstrated that children, women and elderly people may be more sensitive to LAN-induced melatonin suppression compared to the general population<sup>22</sup>. For what concerns children, they have larger pupils and more transparent lenses than adults, so light streams into them more easily<sup>23</sup>.

First investigations about LAN exposure and its hazardous effects have been carried out in occupational settings among night-shift workers and the first studies were conducted among female nurses<sup>24,25</sup>. Indeed, night-shift work is considered a key contributor to LAN exposure, and in 2010 it was classified as a probable human carcinogen (Group 2A) by the International Agency for Research on Cancer<sup>26</sup>. Beside LAN, night-shift work may lead to sleep disturbances, changes in meal timing and lifestyle behaviors,

as well as exposure to other social stressors. For this reason, recent epidemiological studies have focused specifically on LAN exposure and its related effects on human health. Concerning the biological plausibility of an adverse effect of LAN and night-shift work, circadian disruption, melatonin suppression and altered clock gene expression have been proposed as primary mechanisms of carcinogenicity for breast cancer, and for other tumors possibly linked to chrono-disruption of hormone secretion like prostate cancer<sup>27,28</sup>. Beside cancer, night-shift work and LAN have also been linked to increased risk of developing diabetes, heart disease, and obesity in older adults<sup>29</sup>. In this sense, both LAN and night-shift work may interfere with the production of the hormone leptin, playing a role in blood glucose regulation and insulin levels<sup>30,31</sup>. Circadian disruption, elevation in blood glucose levels, and reduced melatonin production may also be the mechanisms involving night-shift work and LAN in cardiovascular disease development<sup>32</sup>.

In addition, there is strong biological plausibility for LAN having adverse effects on mental health, since several physiological processes involved in depression and mood disorders are under circadian control. The neuro-inflammatory responses and some brain regions alterations involved in several mental disorders may depend upon melatonin production<sup>33,34</sup>. Moreover, LAN may indirectly affect mental health causing sleep disturbances, which have been linked to the development of cognitive impairment, particularly in the elderly<sup>35</sup>. Because of the high prevalence of cognitive disorders in older adults and the population ageing, the impact of LAN in such group population holds important public health implications for the possible prevention of mental disorders.

For what concerns children's health, according to the 1996 Protection of Young Persons (Employment) Act, children and young people (aged <18 years) are not allowed to work during night<sup>36</sup>. However, it is estimated that 168 million children worldwide are classified as child laborers, and almost half of them are involved in hazardous work, including night work<sup>37</sup>. Given the illegality of night-shift work in children, data are scarce and mainly focused on their exposure to LAN that can disrupt the body's natural circadian rhythm and interfere with sleep, which is particularly important for child physical and cognitive development<sup>38</sup>. Furthermore, disruption of circadian rhythm has been linked to increased risk of obesity, diabetes, and other chronic health conditions<sup>39</sup>. Those studies, mainly conducted in the United States and Europe, found that children who were exposed to higher levels of LAN had shorter sleep durations compared to those who were not<sup>22</sup>. Other studies linked LAN exposure to increased risk of autism spectrum or attention deficit hyperactivity disorder (ADHD), bipolar disorder, major depressive disorder, dysthymia, specific phobia, and other behavioral disorders<sup>40</sup>. Also, cancer has been included among the adverse effects of LAN in children, such effects being possibly mediated also by exposure during

pregnancy<sup>41</sup>. Suppression of melatonin and disruption of sleep induced by LAN may lead to altered modulation of immune cytokines and inflammation responses, recently investigated in the etiology of childhood leukemia<sup>42,43</sup>.

In conclusion, given the number of people exposed, and considering the most vulnerable groups, LAN appears to be a widespread environmental contaminant, and its possible adverse effects on human health are a key public health issue. Prevention strategies to reduce LAN exposure, such as reducing streetlights and educating people to decrease personal exposure to light, particularly during night hours, are recommended.

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The authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest and none was reported.

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#### DATA AVAILABILITY

Data sharing is not applicable to this article as no new data were created.

#### PROVENANCE AND PEER REVIEW

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