Gezondheidsraad
Health Council of the Netherlands

To the State Secretary for Infrastructure and the Environment

Subject	: Advisory letter *Health risks associated with LEDs*	
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Dear State Secretary,

The use of energy efficient technology is a major pillar of Dutch environmental policy. Incandescent light bulbs were replaced by compact fluorescent bulbs, which – in turn – gave way to LED bulbs. In addition, display screens based on LED technology have become commonplace. It has long been known that people's central biological clocks can be disrupted by artificial light, resulting in adverse effects on their health and well-being. Recent evidence suggests that LED light is more potent in this regard than light from other artificial sources. Aside from the nature of the artificial light itself, there have also been changes in patterns of artificial light use, due to flexible working hours and greater recreational use of display screens. At present, we cannot say whether frequent exposure to LED light (from light fixtures and display screens) is a factor in the occurrence of eye damage. As a precaution, there should be a greater focus on the health risks associated with exposure to LED light. This advisory letter encapsulates the vision of the Health and Environment Surveillance Committee. It was assessed by the Standing Committee on Health and the Environment, one of the Council's permanent bodies of experts.

LEDs are being increasingly used

Due to their long service life and high energy efficiency, LEDs are being increasingly used in lighting fixtures and in the field of IT. Bulbs incorporating LED technology are being increasingly used in public spaces and by consumers.[1,2] Another benefit is that, unlike compact fluorescent bulbs, LED bulbs generate no mercury waste at the end of their service life. New computer screens and television screens increasingly use LED technology, rather than TFT and plasma displays. This is partly due to considerations of service life and energy efficiency, but LED screens are also thinner and provide better picture quality. Another factor is the rapidly increasing popularity of mobile IT and communication devices, such as tablets and smartphones.[3] LED display technology

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is constantly being upgraded. Mobile device display screens are leading the charge in this innovation trend.

Exposure to LED light is increasing

In the future, people's exposure to artificial light in general – and to LED light in particular – is likely to increase still further. This forecast is not based solely on the booming sales of LED-based light fittings and display screens. With each new generation, the intensity of the light emitted by these products increases still further. People are also spending more time watching display screens, not only at home and at work, but also when they are out and about. This is partly a result of flexible working hours and partly because people are spending more of their leisure time viewing display screens. Indeed, they are doing so more often during the dark evening hours than ever before. Broadly speaking, there are two patterns of exposure to artificial light and LED light. One involves background exposure to indoor and outdoor lighting, the other is when light from the screens of TVs, computers, tablets and smartphones shines directly into the eye.

LED light has a distinct composition

Upgrades in the areas of lighting and IT equipment have resulted in changes to the composition of the light emitted by such devices. White light is a mixture of different colours of light. A white incandescent bulb produces relatively little light at the blue end of the emission spectrum, unlike LED bulbs (which people also perceive as being white[a])[4]. The emission spectrum of compact fluorescent bulbs is more erratic. The use of LEDs in display screens has further boosted people's exposure to light at the blue end of the spectrum. So the above-mentioned upgrades have increased people's exposure to blue light. People generally aren't aware of this, because it isn't noticeable. It only becomes obvious when the different types of white light are directly compared.

The biological clock regulates physiological processes and behaviour

Light affects the central internal biological clocks of humans and animals. These biological clocks regulate the cyclical course of numerous physiological and behavioural processes. These include heart rate, hormone secretion, and body temperature, as well as the cycle of sleep and wakefulness. The biological clock is controlled by a small area of the brain known as the *suprachiasmatic*

[a] Same hue (warm or cool) of white.

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nucleus. While this area operates autonomously, it can be influenced by various external factors, the most important of which is light. It is this that synchronises the clock's cycle to the Earth's 24-hour light/dark cycle.

A hormone, melatonin, is involved in the cyclical course of many of the above-mentioned variables. Melatonin production is normally suppressed during the day. However, during the evening and at night melatonin levels rise, which is when people become sleepy. Melatonin derives its nickname of "sleep hormone" from the latter effect. There is no simple causal relationship between light levels and melatonin production. While light levels in the late evening and night lead to the inhibition of melatonin production, periods of darkness during the daytime make people sleepy without any corresponding increase in their melatonin levels.[5-7] The time at which the melatonin level peaks is often used to determine how someone's biological clock is set. Some people are "early birds" while others are "night owls".[8]

The clock's settings are affected by the seasons. They also change throughout life.[8] In the winter, the period of sleep shifts to a slightly earlier time, probably due to the combination of longer nights, later sunrises, and lower light levels in general. As children develop into adults, this shifts to later times. In the elderly, it shifts back again.

The biological clock's mechanism of action has been the subject of a great deal of research (see [9-11], for example). One major breakthrough showed that, for some medicinal products, the time of ingestion or administration determines the effectiveness of the drug in question.[12]

Artificial light can disrupt the biological clock

The use of artificial light during the evening resets people's biological clocks to an earlier time. This is reflected by a delayed rise in melatonin levels. Blue light at wavelengths from 440 nm to 480 nm has the greatest effect.[13-15] This is also the part of the spectrum that makes people most alert. Disruption of the biological clock is thought to be responsible for a range of effects. The short-term effects are shorter periods of sleep, reduced attention and an increased risk of accidents.[13,16,17] Long-term disruption may contribute to the development of cancer, obesity, cardiovascular disease and mental disorders.[18-21] Chronic dysregulation of the clock is a factor in those who do shift work for prolonged periods, for example, and in airline cabin crew who regularly experience jet lag when making intercontinental flights. The Health Council of the Netherlands is preparing a separate advisory report on the effects of irregular working hours on workers' health.

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The inadvertent impact of LED technology

Since they emit proportionally more blue light, white LED bulbs can have a greater impact on an individual's biological clock and alertness than white incandescent bulbs and compact fluorescent bulbs. As a result, the growing market share of LED lighting may inadvertently result in further disruption of people's biological clocks. Various organisations outside the Netherlands, including some EU bodies, have highlighted the ways in which artificial lighting in general, and the light emitted by LED bulbs in particular, can adversely affect the biological clock.[22,23] The increasing popularity of display screens based on LED technology means that these devices are likely to have a similar effect.

Using display screens late in the evening disrupts the biological clock

Several recent studies have confirmed that blue background lighting in the evening can reset people's biological clocks to an earlier time, causing them to stay alert and awake for longer (see[24,25], for example). In addition, the first study has now been carried out into the effects of light shining directly into the eye. The results indicated that working at a computer with a LED display screen for five hours delays the increase in melatonin levels. The subjects involved were found to be less sleepy and better able to concentrate than those who had spent five hours working at a computer with a non-LED display screen.[26] Such LED display screens were found to emit more than twice as much blue light as non-LED display screens. Furthermore, subjects who used a tablet for two hours had lower melatonin levels than those who used the same tablet for the same period of time while wearing glasses that do not transmit blue light.[27] Extra blue LED light reinforces the fall in melatonin levels. Finally, another study found a difference between those who read an ordinary book at bedtime, and those who read e-books on tablets.[28] In the latter group, melatonin levels rose at a later point in time. The subjects in question also took longer to fall asleep and were less alert the following morning. The brightness of their tablets was set at maximum, and the spectrum emitted was rich in blue light. Accordingly, the use of display screens appears to affect an individual's biological clock and alertness in much the same way as blue background lighting.

The social clock is out of sync with the biological clock

In our society, people's social clocks are largely determined by their working hours. On weekdays, "night owls" generally don't get enough sleep, so they need to compensate at weekends. "Early

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birds" get too little sleep if they stay up late. That delays the increase in their melatonin levels, which causes them to feel less fit in the mornings, so they need to compensate at weekends. This causes their physiology to resemble that of "night owls". In addition to working hours, school and college timetables influence many people's social clocks. Various factors, such as the prolonged periods of shift work mentioned above, can cause marked, long-term disruption of the biological clock. Another factor that is known to cause disruption of the biological clock is the annual switch from standard time to Daylight Saving Time, and back again. In many cases, the discrepancy between people's social and biological clocks is chronic in nature and is known as "social jet lag" (analogous to the transient disruption of the biological clock following air travel across several time zones).[8]

LED technology exacerbates the asynchronism of social and biological clocks

For many people, the growing asynchronism between their social and biological clocks goes unnoticed.[8] That's due to social changes such as flexible working hours, incentives to work at home, and the ability to watch TV shows and movies at any hour of the day or night. The increasing asynchronism between social and biological time has, in part, been exacerbated by the above-mentioned upgrades in the areas of lighting and IT equipment. This effect will probably be augmented by the increasing use of lighting and display screens (an ever greater proportion of which are LED bulbs and LED display screens) during the hours of darkness. In a previous advisory report, the Health Council found that people are using display screens in increasingly varied ways, but that the associated health effects are still poorly understood.[29]

Presumably, the extent to which an individual's biological clock is disrupted is primarily determined by their pattern of exposure to light in general. The use of LED technology may have an additional effect. Accordingly, there should be a greater focus on the increasing use of LED technology in lighting and in display screens. These products' long service life is beneficial from the perspective of sustainability, but it also has a downside. It takes a relatively long time before previously purchased products are discarded and replaced by newer models that emit lower levels of blue light.

An individual's biological clock can, to some extent, adapt to a changed lighting regime.[30] In terms of the health and wellbeing of those whose biological clocks are disrupted for extended periods of time, however, the significance of this inbuilt flexibility remains unclear.

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Exposure measurements are worthwhile

Relatively little consideration has been given to the light emitted by TV screens and other electronic consumer goods. Because it shines directly into the eye, such light merits greater consideration. Little is known about the extent to which electronic consumer goods increase people's exposure to blue-rich LED light. Accordingly, more data is needed concerning the spectrum and intensity of the light emitted by these products' display screens. A better understanding is also needed of their patterns of use and of any changes that can be expected in this regard. This information is required for a proper assessment of the extent to which trends in the areas of lighting and IT equipment exacerbate the existing discrepancy between people's social and biological clocks.

The deliberate use of LED light

During the day, repeated exposure to additional artificial light (from LEDs or other sources) can affect an individual's biological clock in ways that are actually favourable rather than disruptive. Artificial light can keep people awake, make them more alert, and improve their cognitive performance.[31] During the day, this is generally considered to be a desirable effect. Moreover, additional light (including additional blue light) during the day can improve the welfare of "night owls".[32] If, immediately after getting out of bed, they are briefly exposed to additional blue background lighting, their biological clocks can be reset to an earlier time. This is reflected by an earlier rise in melatonin levels in the evening. These individuals also suffer less drowsiness during the day. Another potential application is in the treatment of seasonal depression and winter blues. This involves placing affected individuals near a specially designed lamp, and getting them to stare directly at it.[32] Potential applications are also emerging in the field of working conditions. For instance, there is evidence to suggest that people exposed to additional light (including additional blue light) during the working day are more cheerful, more alert and less tired.[33] Finally, there are collective applications that generate beneficial effects. For instance, due to its greater brightness and higher proportion of blue light, the use of LED light as public lighting can have a beneficial effect on people's vision and alertness, resulting in improved safety while driving.

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Light that is too intense can damage the eyes

Aside from disrupting people's biological clocks, light can have yet another undesirable effect – eye damage. Staring briefly at an intense source of light (the sun or an artificial source) can damage an individual's retina and impair their visual acuity (see, for example, the Health Council's 1993 advisory report entitled *Optical radiation*[34]). Blue light is the most harmful, hence the name "blue-light damage".

Partly for this reason, prolonged exposure to less intense blue light is thought to be involved in the pathogenesis of eye disorders.[23] This particularly applies to age-related macular degeneration, which affects the central region of the retina. This condition is irreversible, mainly affects older people, and is a major cause of blindness and visual impairment. However, there is very little epidemiological evidence that prolonged exposure to sunlight and artificial light are involved in the development of age-related macular degeneration.[23] There is even less evidence that the blue component of light is involved.

It is anticipated that 43 percent more Dutch people will suffer eye disorders in 2020 than was the case in 2007.[35] No specific predictions have been made with regard to age-related macular degeneration, but caution indicates that it makes sense to assume that the numbers involved will increase here as well. This projected increase in eye disorders can be partly explained by rising life expectancy. Increasing exposure to LED light may also be contributing to the incidence of age-related macular degeneration.

Safety standards are another reason to investigate the impact of LED light

According to an EU directive on general product safety, consumer products must be safe for users.[36] For lighting, this requirement was crystallised into a follow-up directive.[37] To prevent eye damage, upper limits (which took account of the composition of the emitted light) have been imposed on brightness. The directive is based on a scientific analysis that is widely accepted at international level.[38,39] It is broadly consistent with the above-mentioned 1993 Health Council advisory report.[34]

In that advisory report, the Health Council derived a brightness level for brief exposure (lasting one day) below which retinal damage would not be expected to occur. It also indicates how the composition of the light can be taken into account. It was not possible to prepare a similar analysis for prolonged exposure, due to a lack of data. At that time, several international advisory committees reached broadly similar conclusions[38] and one of them published a supplementary

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advisory report.[39] An international committee in the field of electrical engineering translated the advisory reports into criteria and methods for determining whether the light emitted by artificial light sources is safe for the eyes.[40] These criteria and methods were subsequently included in the above-mentioned EU regulations.[37]

However, the upper limits for brightness are based on data relating to the effects of brief exposure (lasting one day), due to the lack of data on prolonged exposure.[38,39] The resulting uncertainty has been allowed for in the figures. During the past few decades, little progress has been made on closing the gaps in the scientific data.[34,38,39] Indeed, it may not be possible to close them in the near future either. This is an additional argument for further research into the risks of frequent exposure to the blue light emitted by white LED lighting, and to the light from LED display screens.

Conclusions and recommendations

The social and technological developments outlined above are having an impact on the human biological clock. As a result, these may inadvertently have as yet undetected effects on people's health and wellbeing. These effects are not the same for everyone. To some extent, these effects are quite likely to be – or to become – chronic. These include stress, fatigue, sleep deprivation and insomnia. Based on the available data, it is impossible to indicate the current or future scope of these effects in Dutch society. Purely as a precaution, further research into these effects is needed. This recommendation is crystallised in a National Institute for Public Health and the Environment (RIVM) report that is scheduled for publication in the near future.

The widespread use of LEDs in lighting and display screens has led to greater exposure to white light with a larger blue component than ever before. Until recently, the evidence that such light has a stronger disruptive effect on the biological clock than light with a small blue component was limited to studies that focused purely on lighting as the source of light. This has since been supplemented by direct evidence from studies in volunteers using LED display screens for work or reading at unfavourable (in terms of the biological clock) times of the day.

Various organisations outside the Netherlands, including some EU bodies, have highlighted the ways in which artificial lighting in general, and light emitted by LED bulbs in particular, can adversely affect the biological clock. However, they do not examine these effects in a broader perspective. For instance, they take little or no account of developments in the IT field, nor of changing lifestyles in society, which also affect the biological clock. The Committee considers it

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advisable to devote further policy attention to LEDs and their applications, while making allowance for this broader social context.

The biological clock's mechanism of action is well understood. In the light of this, it is clear that, on an individual basis, a tailored approach can reduce any asynchronism between social and biological time. This could involve individuals scheduling their working and leisure times to coincide with periods that are more favourable to their biological clock. The results are beneficial – greater alertness at times when that is appropriate, more sleep, and less social jet lag.

As yet, we can not say whether frequent exposure to LED light (from light fixtures and display screens) is a factor in the development of retinal damage, or whether it exacerbates existing cases. Given the strong growth in the application of LEDs (a trend that is expected to continue), common sense dictates that research needs to be carried out in this area, purely as a precaution.

Technological developments in the area of lighting are already moving in the right direction. For instance, some of the white LED bulbs now being marketed emit a smaller proportion of blue light than the first generations of these devices. However, LED lighting has a long service life, so previously purchased bulbs that emit relatively high levels of blue light will remain in use for some time to come. In the area of display screen technology, relatively little consideration is being given to the relationship between the composition of the light emitted and users' biological clocks. Within the foreseeable future, however, display screens that emit relatively low levels of blue light will be coming onto the market.[41]

Despite the rapid pace of technological development in this area, there is an opportunity to guide it in the right direction by capitalising on the beneficial aspects of LED technology while limiting its adverse effects. The government would be well advised to address these developments, by providing effective guidance. It could, for example, ask the industry to develop bulbs and display screens with even more beneficial emission spectra, and to label the bulbs to indicate the purpose for which they are suited (e.g. bedroom lighting). It is also advisable to inform members of the public (directly or indirectly) about the potential impact that light in general, and LED light in particular, can have on their biological clock, and thus on their health and well-being. This knowledge will enable them to take a rational approach to their use of the various types of bulbs and display screens, both at home and at work. In the context of working conditions, the same applies to employers. This could involve the use of display screens during the hours of darkness, for example. This approach makes sense, given the long service lives of LED bulbs and display screens. Relatively little is known about the spectrum and intensity of the light emitted by the display screens used in TVs and computer monitors. Accordingly, the Committee recommends

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that further research be carried out in this area. Software that adjusts the colour and intensity of light emitted by display screens, according to the time of day, could potentially be very useful. Such software is already available, but it has yet to make an impact on the wider market.[42]

I endorse the Committee's conclusion and recommendations. These are relevant to public health and wellbeing, both at work and during leisure time. Consumer products have an important part to play here. Accordingly, I have also sent this advisory letter to the Minister of Health, Welfare and Sport, the Minister of Social Affairs and Employment, and the Minister of Economic Affairs.

Yours sincerely,
(signed)
Professor J.L. Severens
Vice President

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Annex **A**

The Committee

The Health and Environment Surveillance Committee has the task of bringing subjects concerning health and the environment to the attention of the government and Parliament, and of highlighting threats and opportunities. This may be in relation to new issues but may equally concern topics that require attention once again.

The Committee:

- Dr. F. Woudenberg, *chairman*
  Psychologist, Head of the Environmental Health Department of the Municipal Health Service (GGD) Amsterdam
- Professor M. van den Berg
  Professor of Toxicology, Institute for Risk Assessment Sciences, Utrecht University
- Professor J.W. Erisman
  Professor of Integrated Nitrogen Issues, VU University, Amsterdam; Chief Executive Officer, Louis Bolk Institute, Driebergen
- Dr. P.J. van den Hazel
  Physician, Specialist in Environmental Medicine, Public Health Service Central Gelderland, Arnhem
- Professor E. Lebret
  Professor of Environmental Health Impact Assessment, Institute for Risk Assessment Sciences, Utrecht University; National Institute for Public Health and the Environment, Bilthoven

- Professor R. Leemans
  Professor of Environmental Systems Analysis, Wageningen University and Research Centre
- Dr. J.P. van der Sluijs
  Associate Professor Emerging Risks, Copernicus Institute for Sustainable Development, Utrecht University
- A.J.H.M. Dobbelsteen, *observer*
  Ministry of Infrastructure and the Environment, The Hague
- Dr. A.J.J. van Iersel, *observer*
  Ministry of Health, Welfare and Sport, The Hague
- Dr. P.W. van Vliet, *scientific secretary*
  Health Council of the Netherlands, The Hague

When drawing up this advisory letter the Committee consulted the following persons:
- Dr. T.T.J.M. Berendschot, Medical physics expert, Maastricht University Medical Center +
- Dr. M.G.M. Gordijn, Chronobiologist, Chrono@Work B.V., Groningen
- Professor G.T.J. van der Horst, Professor of chronobiology and health, Erasmus Medical Center, Rotterdam
- Professor J.E.E. Keunen, Professor of ophthalmology, Radboud University Medical Center, Nijmegen
- Professor D. van Norren, Emeritus professor of ophthalmic physics, University Medical Center Utrecht, Leusden

The Health Council and interests

Members of Health Council Committees are appointed in a personal capacity because of their special expertise in the matters to be addressed. Nonetheless, it is precisely because of this expertise that they may also have interests. This in itself does not necessarily present an obstacle for membership of a Health Council Committee. Transparency regarding possible conflicts of interest is nonetheless important, both for the chairperson and members of a Committee and for the President of the Health Council. On being invited to join a Committee, members are asked to submit a form detailing the functions they hold and any other material and immaterial interests which could be relevant for the Committee's work. It is the responsibility of the President of the Health Council to assess whether the interests indicated constitute grounds for non-appointment. An advisorship will then sometimes make it possible to exploit the expertise of the specialist involved. During the inaugural meeting the declarations issued are discussed, so that all members of the Committee are aware of each other's possible interests.