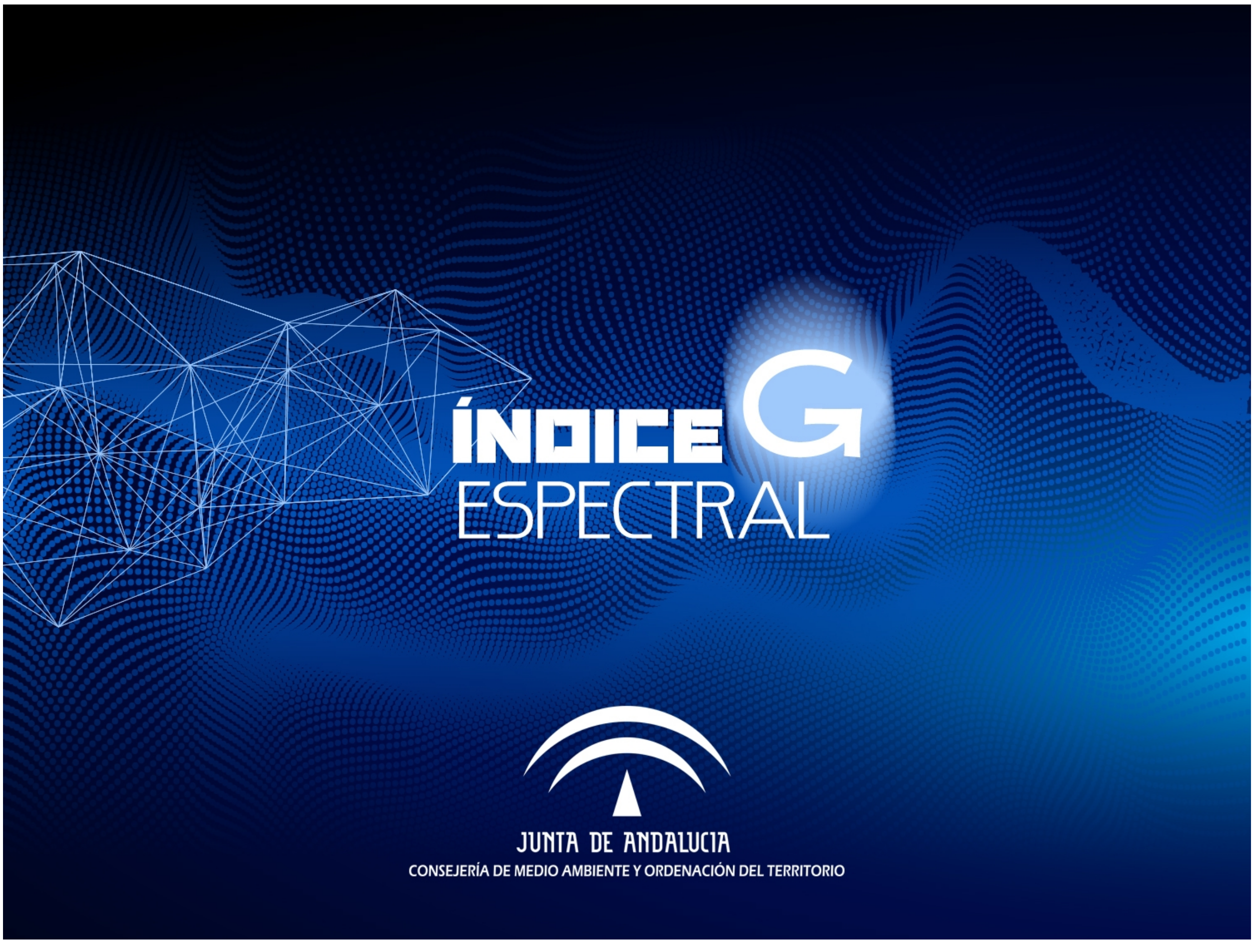

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Avda. Manuel Siurot, 50. 41013 Sevilla
Teléfs. 95 500 35 00 – 95 500 34 00. Fax: 95 500 37 79

CONTENTS

1. INTRODUCTION

The outstanding quality of the night skies over Andalusia is a natural heritage, an identity symbol for our Autonomous Community and, at the same time, a scientific, economic and cultural resource. For these reasons the Andalusian regional government Junta de Andalucía is rising stakes for its preservation since more than one decade ago, through the inclusion of this subject in the regional regulation by means of the Law for the Integrated Management of Environmental Quality (Ley de Gestión Integrada de la Calidad Ambiental) and its ancillary regulation, in year 2010.

Lots of work have been done since then, based on a close cooperation among different administrations, what allowed optimising public resources and establishing a valuable network of collaborators at both national and international levels.

Now, the Andalusian Ministry for the Environment and Land Management (CMAOT, Consejería de Medio Ambiente y Ordenación del Territorio) deals with a new ancillary regulation for the preservation of the natural darkness of night against light pollution. This regulation includes at its core several measures for a sustainable design of outdoor lighting, a key feature to preserve the darkness of night.

To this end, a well suited design has to take into account environmental considerations in general: light has to be shed only where and when needed, with levels and colours adapted to the activities to be developed in the lighted area.

Taking into account that light travels through the atmosphere along distances beyond 100 km, light pollution produced in one area may exert negative effects on another places, even if they are far apart. Thus, public professionals in Andalusia and local governments bear the big responsibility of guaranteeing that the design and management of outdoor lighting are performed under sustainability criteria.

The advantages linked to sustainable lighting come from reducing both the energy costs for municipalities and the emission of contaminants into the atmosphere, and from diminishing the impact on the observation of the sky, on ecosystems and on human health. Including environmental criteria in the processes for the design and management of outdoor lighting means a legal requirement, but it is, also, the best strategy to preserve the sky and its potential as a drive for progress and development.

Among the environmental criteria mentioned, the colour of light is one that has recently become more important, due to the proliferation of white light with a high blue component in recent years. This kind of light has a stronger impact on biodiversity and astronomical observations. Also, according to almost all published studies, light with a high proportion of blue has the greatest effect on health.

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Knowing this problem, CMAOT took part during two years in a working group set by the Spanish Lighting Committee to study the potential risks of LEDs as lighting devices. An astrophysicist from Calar Alto Observatory, Dr. David Galadí Enríquez, proposed a new numerical indicator during the sessions of this working group, the so-called spectral index G.

This indicator characterises the spectral properties of light sources, making possible their quantitative and precise classification depending on the amount of blue light emitted. It has been published in the article "The spectral index system as a tool for the objective, quantitative characterization of lamps" at the *Journal of Quantitative Spectroscopy & Radiative Transfer* (Elsevier). Furthermore, this concept is incorporated as an environmental criterium in the European Commission Green Paper on Public Procurement Criteria for Road Lighting. Also, the spectral index G will be used in the future regulation for the preservation of the natural darkness of night against light pollution, to establish limits to the amount of blue radiation of light sources in Andalusia.

2. PURPOSE

This document provides all necessary information on the G index, to allow its computation by any interested person.

Also, the restrictions linked to this index are given in the shape they will show in the future regulation for the preservation of the natural darkness of night against light pollution.

3. SPECTRAL INDEX G: DESCRIPTION AND COMPUTATION

The spectral index G is an indicator that characterises the spectral properties of light sources, making possible their quantitative and precise classification depending on the amount of blue light emitted, compared to the total radiance that can be detected by the human eye.

For computation purposes, it has to be taken into account that a spectral filter F is defined as a function of wavelength λ, $F(\lambda)$, adopting values from zero to unity. When multiplied by the emission spectrum $E(\lambda)$, the filter selects a specific interval of wavelengths. The resulting filtered spectrum $F(\lambda)\cdot E(\lambda)$ is set to zero for those wavelength values for which $F(\lambda)$ is null, it is equal to $E(\lambda)$ wherever $F(\lambda)$ is equal to unity, and it adopts intermediate values in those wavelengths (if any) where $F(\lambda)$ is between 0 and 1.

The spectral filters used to derive index G are defined as:

a) L500: equal to unity for λ between 0 and 500 nm, null for higher values of λ.

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b) V: equivalent to the curve describing the photopic sensitivity of the human eye, as defined by the standards of the Commission International de l'Éclairage, normalised to maximum equal to unity.

The procedure to derive the index from spectral data measured at laboratories is as follows:

Given the spectrum E of a light source and the spectral filters L500 and V, all defined as functions of wavelength λ as E(λ), L500(λ), V(λ), the spectral index G is computed as the result of multiplying by factor -2.5 the decimal logarithm of the quotient of the integrals of both filtered spectra, placing E(λ)·L500(λ) at the numerator and E(λ)·V(λ) at the denominator. The integrals are made respect to wavelength and in the spectral interval 380-780 nm.

For practical purposes, index G will be computed applying the following formula from the spectrum of a light source E(λ) tabulated with a resolution (table step) of 1 nm, and from the photopic sensitivity function of human sight V(λ) normalised to maximum equal to unity and tabulated with the same resolution:

$$G=-2.5\log_{10}\frac{\sum_{\lambda=380\mathrm{nm}}^{500\mathrm{nm}} E(\lambda)}{\sum_{\lambda=380\mathrm{nm}}^{780\mathrm{nm}} E(\lambda)V(\lambda)}$$

To make easier the calculations, CMAOT has developed a simple tool available in the web.

4. SPECTRAL INDEX G IN THE FUTURE ANDALUSIAN REGULATION

Index G is included in the future regulation for the preservation of the natural darkness of night against light pollution with the aim of establishing environmental requirements for light sources depending on the luminic zones in which the lighting devices are installed. This table summarises these spectral requirements:

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Luminic zone	Spectral index G
E1, E2 or E3 inside E1	G≥2.0
E3	G≥1.5
E4	G≥1.0

In influence areas of reference points, defined as those in which astronomical observatories develop their activities, the regulation will allow only **amber light sources assimilable to monochromatic.** This assimilation is understood as having **spectral index G equal to or larger than 3.5**, effective wavelength in the interval 585-605 nm, and spectrum with equal to or smaller than 25 nm.

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