

THE OPCC EXPERIENCE IN PROTECTING THE SKIES OF NORTHERN CHILE

PEDRO SANHUEZA, HUGO E. SCHWARZ¹, MALCOLM G. SMITH

OFICINA DE PROTECCIÓN DE LA CALIDAD DEL CIELO DEL NORTE DE CHILE- OPCC
CONSORCIO CONAMA AURA CARSO ESO

The Chilean northern skies have unique characteristics which have led to the installation of major astronomical observatories on Cerro Tololo, La Silla, Las Campanas, Cerro Paranal and of the new GEMINI and SOAR telescopes on Cerro Pachon. The recent decision to locate the Large Synoptic Survey Telescope in Chile (at Cerro Parícutin), confirms the quality of Chile's night skies – and the need to continue the work to protect them.

The Office for the Protection of the Quality of the Sky of the North of Chile was created by AURA, CARSO, ESO and CONAMA in the year 2000. Its main purpose is to provide support for the implementation of the Chilean national standard for the regulation of light pollution (the “Norma Luminica”, Decreto Supremo N° 686/1998, Ministry of Economics). This is an environmental standard as it is expected to protect the astronomical quality of the northern Chilean sky. That particular night sky quality is defined as a natural resource by the environmental authority, CONAMA.

The main task of the OPCC is to help people from the north of Chile to become conscious of both the special quality of their night sky and the negative impacts of light pollution. The OPCC also has to provide support for those public agencies in charge of implementing this standard, mainly municipalities (counties) and the Superintendencia de Electricidad y Combustibles – SEC (Office of the Superintendent of Electricity and Fuel). Other tasks of this Office are related to providing technical advice to regulate upper-hemisphere light emissions by means of better outdoor lighting designs, improvements to light pollution monitoring and legislation, by involving the astronomical community, the lighting industry, public authorities and the community.

During the last seven years the OPCC has been working with municipalities and private companies, mainly from the mining industry, providing technical assistance, instruction and diagnosis to fulfil the requirements of the Standard.

Considering only street light in the three regions of northern Chile, 69,668 lighting fixtures (57.65%) have been changed or have funding for that purpose. Current expectations, according to the OPCC, are to replace a further group of 22,690 fixtures by early 2009, thereby bringing the total percentage to 74.44%.

Industry and most of the municipalities of northern Chile are working seriously towards meeting the requirements set by the light pollution standard, although efficiency use of energy remains a pending issue. The main difficulties are related with the medium size and small industries and with the advertising industry as they have to turn off their installation at 1.00 am every night.



Cerro Tololo Observatory

The work of the OPCC

The main tasks of the OPCC are to make people aware of both the unique and distinctive night-sky quality of northern Chile and the negative impacts of light pollution on astronomy, on energy efficiency and on the environment. It promotes quality outdoor lighting, mainly through the implementation of the light pollution environmental standard.

Work has been done in developing devices and methodologies for light pollution monitoring and enforcement. The OPCC has worked with a variety of CCD devices and photographic cameras, using standard astronomical filters and lenses of different focal lengths; these devices include the so-called All Sky Cameras, which were developed in AURA for continuous monitoring of the night sky - by Roger Smith and Dr. Hugo Schwarz. OPCC has also tested some photometers and is now embarking on a program of measuring and comparing sky brightness at different observatory sites like Cerro Tololo, Las Campanas and Cerro Pachon.

This office constantly looks for funding for the programme of massive replacement of municipal lighting fixtures which do not comply with the standard. It has been relatively easy to convince authorities to replace old-fashioned lighting systems, as most of them tend to fail and consume too much energy, without providing good outdoor illumination. In the case of the large businesses in northern Chile (mainly mines), the results are also interesting, as most of these companies have been replacing old, inefficient systems with new lighting products that comply with the standard. Among others, the following companies have all obtained good results in adapting or replacing their lighting systems: Compañía Minera Carmen de Andacollo Mining, Compañía Minera Dayton, Compañía Minera del Pacifico, CODELCO, Mantos Verdes, Mantos de Oro, Compañía Minera Candelaria, Compañía Minera Meridian, Minera Los Pelambres, Minera Saldivar, Soquimich, Norgener and Finning.

The light pollution standard is located under the umbrella of environmental legislation in Chile. This has provided a consistent institutional framework and public involvement. The work of the OPCC has also been favoured by a generalized positive attitude towards science, particularly through astronomy, in all levels of Chilean society.

For many years in Chile the lighting engineering and energy-efficiency areas have suffered from severely limited technical support and development. In that sense, the OPCC has had to cover part of this weakness in northern Chile. That is also why this office has been



Magallanes Observatory at Cerro Las Campanas.

perceived as a positive partner for municipalities and companies when they embark on updating their old-fashioned outdoor lighting systems. This may also explained why municipalities in southern Chile - or even from other countries – have welcomed the technical advice provided by OPCC.

The OPCC is an active component of the Chilean program for energy efficiency – a public and private initiative under the umbrella of the Ministry of Economics. The role of the OPCC has been to promote energy efficiency and responsible outdoor lighting management by means of controlling light pollution and power consumption. For that purpose, the OPCC follows the technical recommendations coming from The CIE (the International Lighting Commission) and Chilean electrical legislation.

The Superintendencia de Electricidad y Combustibles, SEC, is the national institution in charge of enforcement of light pollution legislation. They also receive the technical support of the OPCC, mainly in the area of diagnosis, lighting techniques and instrument development.

Results

The Region of Antofagasta has brought 71% of its street lighting into compliance with the light pollution legislation. The main city of the region, Antofagasta (pop. 360,000; 120 km from Cerro Paranal observatory) is now working on its terms of reference for replacing almost 9,500 more lighting fixtures. So it is expected that, by the year 2009, almost 100% of their public street lighting fixtures will be complying with the 686/98 standard. Tocopilla, a small municipality (pop. 23,986) has finished the replacement of 950 fixtures and it is expected that, during the last semester of this year, it will start working on replacing another big group of them.

65% of the public street light in the Region of Atacama now comply with the light pollution standard. In this Region there is significant unemployment and economic depression, so the results already obtained in the area of light pollution control and energy efficiency are truly remarkable.

Copiapo, the main city of this region, replaced almost 90% of its polluting luminaires in 2001. The municipality of Huasco replaced a similar proportion of lighting fixtures in 2003. Almost 300 of these new luminaires were equipped with double-ballast technology, as part of a quality-lighting approach emphasizing energy efficiency.

In the case of the Region of Coquimbo, there have been some unexpected difficulties in the approval of the terms of reference for replacing almost all the polluting lighting fixtures of 11 municipalities. The necessary funds (available since 2006) are now expected to be spent during the coming year. If the replacement goes according to current plans, during 2009 almost 80% of lighting fixtures in the region will be complying with the light-pollution standard. The city of Coquimbo (50 km away from Cerro Tololo, pop. 160,000) is likely to remain in an illegal condition even into 2009.

Apart from that exception, the overall results are very encouraging. It should be realized that, by the year 2000, only about 5% of the lighting fixtures in northern Chile fulfilled the light pollution standard. Now, the figures show an average of 57% compliance across the three Regions.

The role of the SEC, mainly in the Regions of Antofagasta and Atacama, has been

significant in getting these results, mainly in the case of new electrical installations and in respect of environmental impact assessment.

Legal aspects

The light pollution standard, known as the Regulations for Controlling Light Pollution, Supreme Decree N 686 of the Ministry of Economics, was enacted in 1998 and came into force in October, 1999. Its main objectives are to restrict light emissions into the upper hemisphere and to restrict radiations from lights at frequencies to which the human eye is not sensitive. But these (environmentally friendly) objectives avoid pointless energy waste and will specifically help to protect the night sky.

Maximum allowed limits

The main requirement for public lighting, ornamental lighting, floodlights, illumination of businesses and of private buildings is related to limiting upper hemisphere emission to a range from 0.8% to 5% of the total flux of the lamp being installed in the fixture, depending on the application. Secondly, the lower limit for lighting efficiency for public and business lighting must be at least 80 lumens per watt.

For sport facilities, recreational activities and advertisement there is a time restriction: sport and recreational activities must turn off their lights at 2 am and billboards at 1 am. Otherwise, they have to comply with the regulations for public street light lighting.

The main limits are given in the next table:

Table 1. Maximum limits

Type of Illumination	Effective Luminous Flux	Upper Luminous Flux	Lighting Efficiency	Time Restrictions
1) Public roads, industry, mining, parkings, business and private buildings.	<= 15,000 lum	<= 0.8 %	>=80lum/watt	No
	> 15,000 lum.	<= 1.8 %	>=80lum/watt	
2) Lighting fixtures and floodlights in gardens, beaches, public parks, including building and monument ornamental lighting.	<= 9,000 lum	<= 5 %	No hay	No
	>9,000 lum	Subject to 1)	Subject to 1)	
3) Sport and recreational facilities. (*)	No	No	No	From 2 a.m. they will be regulated as 1)
4) Advertisement (**)(**)	No	No	No	From 1 a.m. their Upper Luminous Flux shall be lower than 0.8% of their Effective Luminous Flux
5) Laser Floodlights(**)	No	No	No	From 2 a.m. they shall be oriented below horizontal

(*) Time restrictions indicated for 3); 4) and 5) will start one hour after the time indicated on Saturdays, Sundays and holiday days.

(**) This percentage will not be applicable to advertisements within commercial enclosures while they are open to the public.

Illumination of industrial and mining areas, of parking lots, of business and private buildings, floodlights, illumination of gardens, beaches, public parks, including ornamental and monument illumination had to be adapted in 2004. Public lightening was adapted in 2005

“Grace period” for reaching compliance

One important feature of the standard is a series of time periods given for different light sources to come into compliance. This is a typical strategy of the Chilean environmental legislation – be flexible not with the results but with the period of time allowed to fulfil the requirements. Public lighting had six years to adopt the light pollution standard – the grace period for public lighting ended in October 2005.

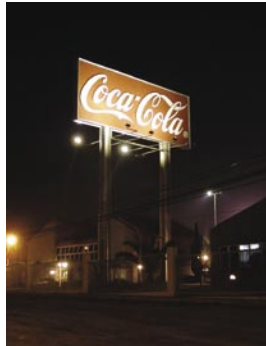
For businesses, for ornamental lighting and for the use of floodlights the grace period expired in October 2004.

The other sources of light emissions do not need to comply with expiry date requirements, as they have to turn off their lighting installations at 1 am, in the case of billboards, or at 2 am in the case of open-air sports and recreational facilities. For that reason, they have had to comply with the standard from the very beginning – i.e. from October 1999.

Implementation

Application of the light pollution standard has proven reasonably straightforward in practice. Since the photometric labs have to do all complex calculations and tests, the users or authorities have a much simplified job. They have to follow the instructions given in the photometric reports – normally the main skill required involves checking the angles of installation of the lighting fixtures or floodlights. For this, they have to use simple devices like angle finders to verify compliance with the light pollution standard. And when checking open-air sports courts or recreational facilities, all the SEC needs is a clock. The OPCC had developed a simple angle finder with the help of AURA and the Photometric Laboratory of Universidad Catolica de Valparaiso.

The primary parameter of the light pollution standard is the maximum luminous flux allowed by the luminaire into the upper hemisphere; this is established for a given type of luminaire in the photometry lab. The upper luminous flux measurement is normally made to get the overall efficiency of luminaires. It is not typi-



New challenges: adaptation and time restrictions for illuminated advertisements.



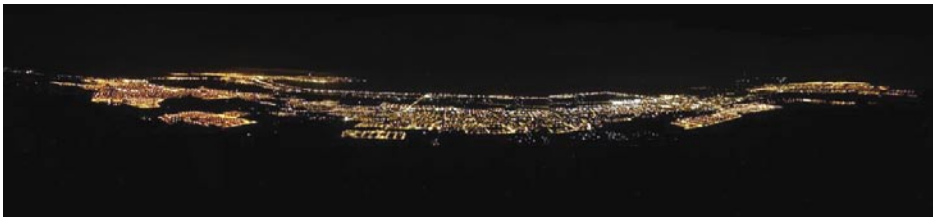
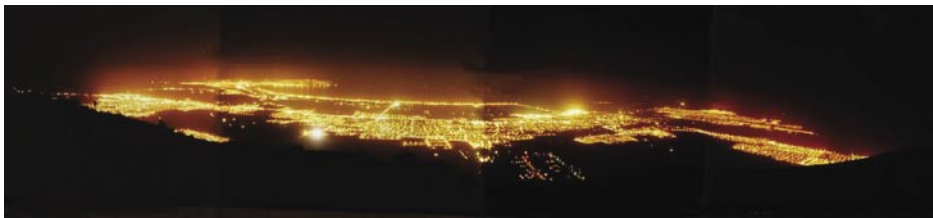
Angle finder to check luminaires installations

PONTIFICIA UNIVERSIDAD CATÓLICA DE VALPARAISO - CHILE 1-7									
LABORATORIO DE FOTOMETRÍA			ESCUELA DE INGENIERÍA ELÉCTRICA			FACULTAD DE INGENIERÍA			
<small>Conforme a los valores Fotométricos controlados en este informe, la luminaria satisface la Normativa contenida en el D.S. N° 486/96, sobre CONTAMINACIÓN LUMINOSA.</small>									
FOTOMETRÍA: LUMUCV - 1972603			EXPEIDIDA: 10 de Septiembre de 2003			REVISÓ: 			
LUMINARIA: MODELO JCH			MARC A: CARANDINI			FOTOMETRÍA SOLICITADA POR: ALADDIN LIGHTING			
REALIZADO POR: Juan Riquelme Piñero									
CLASIFICACIÓN LUMINARIA SEGÚN ANSIES IEP, 4977					RENDIMIENTO HEMISF. INT. V. S.F.P.		DATOS LAMPARA		
TIPO	I	O	II	X	O				
						INTERIOR CALZADA : 49,30 (%)		TIPO: SOFIDO	
INTERIOR VERTICAL	X	O	O	X	O	INTERIOR VEREDA : 16,30 (%)		POTENCIA: 70 (W)	
COROA						SUPERIOR : 0,44 (%)		FLUJO: 6000 (LM) (NO MINIMIZADO)	
CONTROL	O	X	O	O	O	TOTAL : 66,04 (%)		CURBID: Variable	
CUT OFF									
CONTENIDO FOTOMETRICO					DIMENSIONES SIGNIFICATIVAS DEL SISTEMA OPTICO (mm)				
1-7- BOTULOS					A: 68				
2-7- PLANO Y CONO DE LA INTENSIDAD MAXIMA					B: 85				
2-7- DIÓLUX					C:				
4-7- ISOCANDELAS					D:				
5-7- COEFICIENTE DE UTILIZACIÓN					E:				
6-7- DIAGRAMA DE CLASIFICACIÓN					H: 80				
7-7- TABLA DE INTENSID.									
					<small>REFLECTOR: ALUMINIO ANODIZADO TENSION DE ARCUO BUENITO DE LA LUMINARIA: 90,8 - 17% REFLECTOR: NINGUNO PLANO TENSION DE ARCO FUERA DE LA LUMINARIA: 90,8 - 17% LA CUERVA DE L.L.C. AL INSTALAR LA LUMINARIA. DIFUSION DE BEBEBOTON: 300 360 0000</small>				
CARACTERÍSTICAS FOTOMÉTRICAS DE LUMINARIA PARA ILUMINACIÓN PÚBLICA									

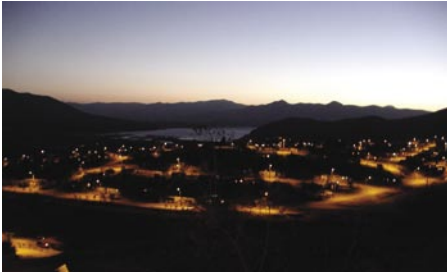
A photometric report for a lighting fixture

Photometric report for compliance with the light-pollution regulations.

The following chart shows a photometric report released by the Photometry Laboratory of the Universidad Catolica de Valparaiso. This report provides the necessary certification to establish compliance which the light pollution regulations. In the red box can be seen the angle of location of the lighting fixture, in which it must be installed to fulfil the given requirement. In this particular situation the luminaires must be installed at 0° to provide a total upper hemisphere emission of <0.44% of the whole emission of the lamp in this fixture. Given that in this situation a maximum of 0.8% of total emitted



Two views of La Serena before (above) and after changing the luminaires (below, October 2005, OPCC Northern Chile).



Monte Patria: 3.500 luminaires before and after their substitution with double-ballast technology.

flux is permitted, this luminary complies with the Chilean standard.

As we have discussed, for lighting technicians, it is simple to verify compliance with the standard. Most of their job is to install the luminaires at the correct angle.

Review of the standard

At this time CONAMA (Chile's National Commission for the Environment) is leading a review of the light pollution standard. As the standard is treated as a piece of the environmental legislation, it has to be subjected to periodic review.

The main issues to be considered are the following:

It is important to differentiate between advertisements that are internally illuminated from ones that are illuminated externally, usually using floodlights, as they are of a different nature. In order to establish the maximum limit of emission of the first kind, CIE luminance values should be applied.

Two values are given in the Chilean standard as limit for the upper-hemisphere emission for street-light fixtures. An upper limit of 0.8% is set for luminaires emitting equal or less than 15,000 lumens. For values over 15,000 lumens, the permitted upper flux is 1.8% of the total emission of the fixture. The proposal is to establish a unique upper percentage flux for street lighting, perhaps a value of 1%.

The more significant and difficult revision is the one related to maximum levels of illumination for outdoor installations. Ground reflectivity is a significant factor affecting net upward light in the case of excessively powerful but otherwise compliant lighting installations, and also there is a matter of energy efficiency. Over illuminating is one of the main problems that municipalities and mining companies have in northern Chile, in this area. The proposal of OPCC for solving that problem at this stage is to look for a way of not exceeding the lighting values already established in the international recommendations of CIE and in the national legislation. The current CIE recommendations only establish minimum values.



In the case of the large businesses in northern Chile, and the mining sector in particular, the results are also interesting, as most of these companies have been replacing old, inefficient systems with new lighting products that comply with the standard.

Considering the restrictive international and national energy panorama, SEC has been developing new public lighting legislation, taking into account the light pollution standard. They are including in this proposal energy efficiency and light pollution criteria. One of the problems to be faced in this new legislation is the one related to set maximum lighting limits. We are, nevertheless, still some way off being ready to introduce and tackle the issue of lighting zones in Chile, with appropriate lumen caps.

OPCC proposal to Starlight

As the Starlight initiative has been gaining relevance potentially significant at international level, the OPCC proposes some issues to be discussed in the near future:

- Starlight should promote the implementation of the second world atlas of the artificial night sky brightness, by Cinzano, Falchi and Elvidge.
- The CIE recommendations should include maximum levels of illumination.
- CIE recommendations should also establish more explicit criteria to classify streets and highways. Otherwise, the implemented lighting values vary significantly among lighting engineers.
- There is an important and permanent lack of participation of underdeveloped countries in CIE. This problem should be faced. Eventually it will be time to promote the organization of regional CIE committees.
- OPCC proposes the creation of a Lighting Commission for South America. This organization should interact in a better way with CIE. This LCCA organization should be located in Brazil.
- Lux-America could evaluate the current status of light pollution and energy efficiency in their countries.
- The national reports on light pollution could be reported by Lux-America to UNESCO or PNUMA.
- Starlight should interact permanently with UNESCO, PNUMA, CIE, AUI, IDA and other relevant international organizations of a similar nature.
- It could be significant to have an international agreement among researchers for light pollution monitoring.
- Starlight should promote the Globe at Night activity, especially in countries which are not participating now in this campaign.
- Starlight should promote environmentally-friendly night technologies, mainly in under-developed countries.

Notes and References

1. Hugo Schwarz died in October, 2006, but contributed significantly to the work described in this paper. CINZANO, P., 2005. Night Sky Photometry with Sky Quality Meter. ISTIL International Report N°9.
2. CINZANO, P., FALCHI, F., ELVIDGE, C.D., 2001, *The First World Atlas of the artificial night sky brightness*. Mon. Not. R. Astron. Soc., 328, 689-707.
3. SCHWARZ, H. Editor. 2003. *Light Pollution: The Global View*. Proceedings of the International Conference on Light Pollution, La Serena, Chile, held 5-7 March 2002.