Anthropogenic Light At Night
Towards Standardized Measurement Methods & Criteria as a Policy Tool

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Chair of CIE TC2-95 “Measurement of Obtrusive Light and Sky Glow”
“State of the art” in Obtrusive Light (light pollution)

The triplet of “success”

- Increase of outdoor lighting
- Bad design & engineering
- Inappropriate products
“State of the art” in Obtrusive Light (light pollution)

- Microscopic or Near-field
“State of the art” in Obtrusive Light (light pollution)

- Macroscopic or Far-field
Mitigation of negative effects

- Numerous recommendations
- Local laws are initiated by various stakeholders
- Laws target to various mitigation strategies
- Law makers seek for scientific evidence
- Laws frequently follow other laws or adopt international guides
- Decision makers want to have strong argumentation
- **Law “enforcement”** is secured by field measurements
Metrology of … things

Measurement Quantity

... well-“defined”

Measurement Devices

... well-“prepared”

Measurement Uncertainty (& Conformity Assessment)

... well-“estimated”
Need for metrology base on obtrusive light

... accuracy, precision, error, uncertainty, tolerance ...

Source: CIE TN 009:2019 - The Use of “Accuracy” and Related Terms in the Specifications of Testing and Measurement Equipment
Units and quantities

Quantities shall be expressed in internationally agreed units (i.e. reference quantities): The SI

**Just an example:** Effective irradiance

\[ E_{\text{act}} = \int E_\lambda(\lambda) A_{\text{act}}(\lambda) \, d\lambda \]

Units: \( \text{W} \cdot \text{m}^{-2} \) \( \text{W} \cdot \text{m}^{-2} \cdot \text{nm}^{-1} \) dimensionless \( \text{nm} \)

Different quantities may have the same units.

In obtrusive light we may define more complicated action spectra including directionality, time dependency, distance, etc.
Aspects of obtrusive light

- photons propagate
- photons are reflected
- photons intrude
The “sources” of the problem

- Domination of LED in new installations
- Combination of conventional and colorful light sources
- Dynamic character especially on colorful scenes
- Luminous intensities and lighting distributions can vary significantly
Our current fight tools

- Various spectral responsivites
- Each instrument was developed for different purpose
- Possible issue for the measurement of narrow band sources
- Limited number of filters are standardized or well defined
- Most of them do not offer traceability
Metrology of obtrusive light

Measurement Quantity
- Link to photopic units
- Link to radiometric units
- New quantities?
- New action spectra?

Measurement Devices
- Many types
- Lack of standardization
- Lack of calibration
- Lack of methods
- Lack of traceability

Measurement Uncertainty (& Conformity Assessment)
- Metrics?
- Uncertainty evaluation?
- Lot of work ahead

Sanchez at al.
**Need for a metrology base on obtrusive light**

<table>
<thead>
<tr>
<th>Action spectra</th>
<th>Quantities</th>
<th>Metrics</th>
<th>Instrumentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Human based</td>
<td>- Photopic</td>
<td>- For sky glow</td>
<td>- Proper for each quantity</td>
</tr>
<tr>
<td>- Species based</td>
<td>- Radiometric</td>
<td>- For reflected light</td>
<td>- Ensure traceability</td>
</tr>
<tr>
<td>- Sky glow based</td>
<td>- … other</td>
<td>- Environmental impact</td>
<td>- Estimate uncertainty</td>
</tr>
<tr>
<td>- … other</td>
<td>(linked to SI units)</td>
<td>- … other</td>
<td>- Establish interoperability</td>
</tr>
</tbody>
</table>

**Instrumentation**

- Proper for each quantity
- Ensure traceability
- Estimate uncertainty
- Establish interoperability
Metrology of obtrusive light as a policy tool

- Measurement and monitoring of all aspects
- Dedicated methods and instrumentation
- Inter-disciplinary adoption
- Dedicated assessment criteria
- Verification of lighting installations.
- Measurement schemes should be implemented in regulations.
- Mitigation and restoration when scientifically justified thresholds are exceeded.

Legislation

Mitigation

Assessment

Measurements
CIE TC2-95 “Measurement of Obtrusive light and sky glow”

Terms of Reference

To provide guidelines and examples for metrics, measurement methods and corresponding instrument specifications for the measurement of obtrusive light and sky glow including the estimation of measurement uncertainty contributions for the measurement, necessary to validate assessment criteria of its effects on the environment. The proposed guidelines and examples can be used as a common base with reliable and traceable techniques for various disciplines that are dealing with obtrusive light and sky glow measurements, light pollution assessment and research.

TC work ⇒ Internationally agreed Technical Report ⇒ Adoption by local laws

more at: https://cie.co.at/technicalcommittees/measurement-obtrusive-light-and-sky-glow

CIE – International Commission on Illumination
“Takeaways”

● Standardized measurements, methods, and criteria
  ○ support research
  ○ strengthen evidence
  ○ ensure communication
  ○ validate mitigation measures
  ○ support legislative actions

● Towards standardization
  ○ combination of research evidence
  ○ develop quantities, metrics and assessment criteria
  ○ develop measurement standards and guides

● Long-term target: Integration into national and international laws
Thank you for your attention!

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