Response To Öko-Institut

regarding the

1st Questionnaire Exemption Request No. 4(f)

"Mercury in other discharge lamps for special purposes not specifically mentioned in this Annex"

Date of submission: September 15, 2015

Name and contact details

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With support from:

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Abbreviations and Definitions

Hg Mercury

LEU LightingEurope

Background

The Oeko-Institut has been appointed within a framework contract[1] for the evaluation of an application for granting an exemption to be included in or deleted from Annexes III and IV of the new RoHS Directive 2011/65/EU (RoHS 2) by the European Commission.[1]

LightingEurope has submitted the above mentioned request for exemption which has been subject to a first evaluation. The information you have referred has been reviewed and as a result we have identified that there is some information missing and a few questions to clarify concerning your request.

Questions

1. LEU stated that lamps covered by Ex. 4(f) have higher internal pressure compared to fluorescent lamps falling under other exemptions.

    a) Please support this with the help of technical parameters related to application specifications (i.e. for the lamp sub-groups said to fall under the scope of this exemption);

    b) Please clarify the differences in internal pressure between Ex. 4(f) lamps and other fluorescent lamps in general and particularly lamps falling under Ex. 4(a) (low pressure, no phosphor coating, unique UVC range).

    Answer of LightingEurope: See point 3 of the renewal request for exemption 4f. The statement has been made as exemptions 1a-f, 2a, 2b, 3a-c, 4a and 4g are covering all so-called low pressure discharge lamps available on the market for general lighting as well as for special purposes. The mercury pressure in fluorescent/low pressure discharge lamps corresponds to the equilibrium pressure of mercury vapour above the liquid mercury (or even lower in certain cases). As the temperature of the mercury is relatively low in the lamps falling in exemptions 1, 2 and 3 the mercury pressure is in the order of 1 Pa.[2] In exemption 4a the wall temperature is higher, but here usually an amalgam is used to regulate the pressure to about 1 Pa. The IEC has defined low pressure lamps as lamps having a mercury pressure below 100 Pa[3]. All lamps with low

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[1] Contract is implemented through Framework Contract No. ENV.C.2/FRA/2011/0020 led by Eunomia

[2] The mercury (equilibrium) pressure above mercury is critically evaluated by NIST „The Vapor Pressure of Mercury“ Marcia L. Huber, Arno Laesecke, Daniel G. Friend, NISTIR 6643.
http://www.physics.rutgers.edu/~eandrei/389/NISTIR.6643.pdf

[3] The definition of a low pressure lamp: http://www.electropedia.org/iev/iev.nsf/display?openform&ievref=845-07-22
The definition of a high pressure lamp: http://www.electropedia.org/iev/iev.nsf/display?openform&ievref=845-07-20

pressure discharge technology (exemptions 1a-f, 2a, 2b, 3a-c, 4a and 4g) do have a mercury limit.

The scope of exemption 4(f) is thus covering those lamps, which

- are non-fluorescent,
- and have higher internal pressure compared to fluorescent lamps (>100 Pa)
- and are used for special purposes

In exemption 4f the dosed mercury is fully evaporated. The mercury pressure is orders of magnitude higher and varies hugely for the different lamp types: roughly form 25 kPa to 35 MPa as listed in the table below.

Exemption	**Lamp sub-groups**	**Internal pressure**	**Application specification**
1a-f, 2a, 2b, 3a-c, 4g	Fluorescent lamps (CFL, linear and non-linear FL, Cold cathode FL)	200 Pa ~ 700 Pa by noble gas, 0.1 Pa ~ 5 Pa by Hg	General lighting and special purposes,
4a	Other low pressure discharge lamps	200 Pa ~ 700 Pa by noble gas, 0.1 Pa ~ 5 Pa by Hg	Germicidal and other UV
4f	Lamps for projection purposes	10~35 MPa	White light Point source
	Short arc mercury lamps	1~5 MPa	High intensity light, point source
	High Pressure Sodium	0.1~0.8 MPa	Horticulture and other special purposes
	UV curing lamps	1~5 MPa	Spot area
		0.1~1 MPa	Plane area
	Other high pressure	> 1 MPa	

Table 1: Overview of Hg pressure in different lamp types:

2. From other applications for the renewal of this exemption, it appears that the exemption could be limited to discharge lamps operating mainly in the UVB-UVA spectrum.

   a. Please state if you agree with this proposal or not;

   b. If relevant, please specify the relevant spectrum to which the exemption could be limited.

   Answer of LightingEurope: LightingEurope and other affected industry associations clearly disagree. It is correct, that many lamps are used in applications using UV light. But there are also other lamps, e.g. projector lamps, UVC medium pressure lamps, High Pressure Sodium (HPS) lamps for special purposes. So visible light sources are in the scope as well, see also Table 1 of the exemption renewal request (Examples of lamps and applications for exemption 4(f)) as well as Chapter 4(C), p14 .

Low pressure UVA, UVB and UVC lamps are covered by exemptions 1f, 2b4 or 4a.

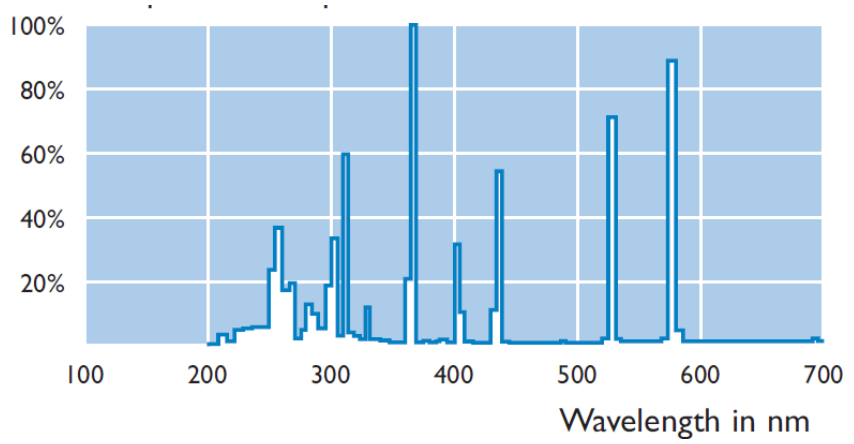


Figure 2: Example for the spectrum of a medium pressure lamp for water purification

The majority of medium pressure UV curing applications (drying of inks, coatings, adhesives etc) use UV across a wide range of wavelengths from UVC, to UVB and UVA; so from 280 – 420nm, delivered by the broad band emission from the current bulbs containing mercury. For any given application, this use of the broad band emission takes place in a fraction of a second with all wavelengths being absorbed and utilised simultaneously. This optimises a match with the absorption characteristics of the photoinitiator packages that are commercially available and widely used. The ability to use all the UV spectrum enables the UV curing process to deliver coatings which have hard, scratch resistant surfaces (UVC/UVB) and depth of cure to ensure good adhesion, toughness and ability to cure pigmented coatings (UVB/UVA).

Also for water disinfection applications only UVC will work (needed to destroy DNA) and LEDs do not have output at these wavelengths with sufficient power.

LightingEurope sees no relevant spectrum to which the exemption could be limited.

We strongly encourage the consultant not to change the wording of the exemption, as it covers “other lamps not specifically mentioned in the Annex” which is a very in-homogenous group but different to low pressure discharge lamps mercury overdosing is influencing lamp parameters leading to lamps out of intended specification.

3. Please clarify if phosphor coatings are used in lamps falling under this exemption or if this aspect could also be added to the exemption wording to limit its scope to applications for which it is actually used;

Answer of LightingEurope: According LightingEurope understanding lamps using phosphors are usually falling in exemptions 1-3 (plus 4g). But the use of specific phosphors cannot be excluded for some High Pressure lampsfalling in 4f.

Even LED modules can use phosphors.

4. You explain that there are four common dosing technologies for lamps explained to fall under Ex. 4(f), for example, mercury-sodium amalgams Na-Hg (ca 20% Hg).

   a) Respectively, please detail for each dosing technology in which lamp types (UV lamps, protector, HPS etc.) it is used.

      Answer of LightingEurope:
      Manual pipetting or needle injection of liquid mercury (100% Hg)
      ➔ UV lamps (e.g. Short Arc Mercury lamps)

      Semi- or fully automatic dosing, disc needle injection of liquid mercury (100% Hg)
      ➔ Projection lamps, UV lamps

      Mercury-Sodium amalgams Na-Hg (ca 20% Hg)
      ➔ High Pressure Sodium lamps (Horticulture lamps)

      Amalgam sticks (ca. 20-50% Hg)
      ➔ High Pressure Sodium lamps (Horticulture lamps)

      Liquid dosing is applied to lamps either manually or in automated injection technologies. The choice is more related to production technologies and number of produced products.

   b) For each of these groups, please provide data concerning the range of mercury applied in lamps falling under ex. 4(f) as well as average values;

      Answer of LightingEurope: See table 2 of the renewal request, chapter 5, page 13. It contains mercury ranges as far as applicable for 4f lamps.

   c) Please clarify if a differentiation of Hg allowances could be made on the basis of typical amounts used for lamps manufactured with each of the typical dosing techniques or in respect of application sub-groups related to another parameter.

      Answer of LightingEurope: Mercury content in lamps falling in exemption 4f is very specific per lamp. Mercury in discharge lamps is already differentiated to a very high extent. Further differentiation within exemption 4f would not lead to reduction of mercury, neither in specific lamps nor in the overall amount put on the EU market unless certain lamp types would be excluded unintentionally. These exemption covers a very in-homogenous group where, different to low pressure discharge lamps, mercury overdosing is influencing lamp parameters leading to lamps out of intended specification.

5. It is explained that UV LED lamps are available and may be considered as an alternative technology for medium pressure mercury lamps used in UV curing applications, but their performance characteristics are said to be very different to UV mercury lamps.

   a) To support such views, please provide detailed quantitative data (table overview) to clarify application specifications and differences between Ex. 4(f) lamps and such candidate alternatives (see also requests of VDMA e.V. and VskE4)

Answer of LightingEurope:

See text in chapter 6A of the renewal request on pages 19ff. For UV-curing specifically see pages 21-23. Two major issues can be distinguished:

1. **UV-Light and Chemistry:** UV LED lamps are a developing technology but currently, the use of these lamps in UV curing applications for the drying of inks, coatings and adhesives has found some limited success in some niche applications within the very wide range of commercial UV curing markets. There are significant limitations with current UV LED lamps that arises from the mismatch between the readily available commercial photo initiators and the light output from LEDs (both wavelength and dose). Where there is a match, they can be used only in a limited range of applications, as mentioned in the renewal request, due to the lower energy output and limitations in the positioning of the UV LED lamps relative to the coating to be cured. See "Technical details" below for further explanation if needed.

2. **Replacement in the field:** In most cases retrofit of UV LED lamps is not possible as 4f lamps are used in specific equipment with specific drivers, ballasts, optics, architecture, application, ink chemistry, etc. As described in Ch. 6, p.19ff of the exemption renewal application. Most UV applications are designed and specified using a specific lamp and any change of the lamp technology can be expected to have an impact on performance, safety and other properties.

In addition, lamps have to be replaced several times over the life-time of the equipment. The replacement lamps must fit into the existing fixture, and must deliver the same performance, safety and reliability, which the equipment was designed and tested for. It should also be recognized that lamps are consumable items that are mainly utilized in high value equipment which is already in service. The systems were designed for mercury lamps and there is no alternative chemistry that will produce a suitable spectral output that will operate with the power electronics contained within the existing plant. Hence, even if a new technology becomes available in the future, there will be a requirement for mercury lamps as replacement spare parts for legacy capital equipment for a considerable period.

Technical details of "UV-Light and Chemistry"

The main difference between UV LED lamps and Hg lamps is in the spectral output for the lamps, that is, the narrow band emission of the UV LED and the broad band emission of the Hg lamps. Currently for UV LED lamps with output 385nm, 395nm and 405nm are available for use in commercial applications. A separate UV LED lamp, with its own

[4] Please see: http://rohs.exemptions.oeko.info/index.php?id=238 for application documents related to this exemption.

power supply and cooling requirements, are required to produce each wavelength. Whereas the Hg lamp produces all of the above wavelengths and many others from 200-420nm from the one lamp.

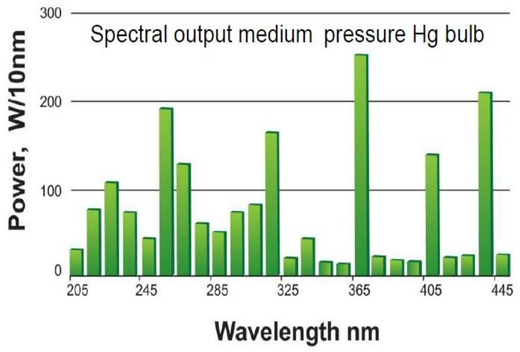
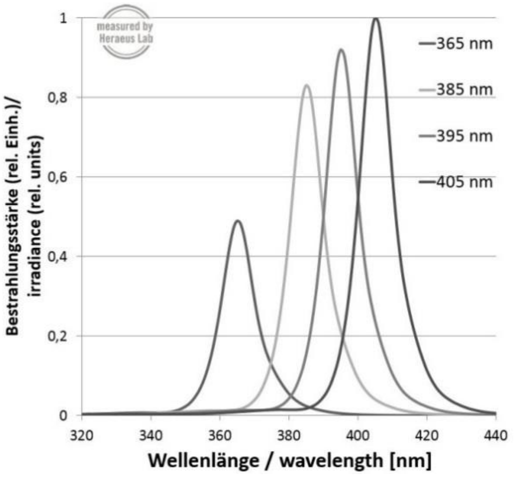


Figure 2: Spectral output of medium pressur mercury lampsiiiiiiiNearly



This overlap between the absorption spectrum of the photo initiators and the emission spectrum of a UV lamp is a critical factor in ensuring that the UV curing process is as effective and productive as possible, and that the final coating delivered by the process has the required properties. Most formulations for inks, coating and adhesives require a wide range of UV wavelengths (which match the absorption profile of the photo initiators) to produce coatings with a mix of hard, scratch resistant surface together with depth of cure to ensure good adhesion, toughness and flexibility. For example UVC and UVB (280-320 nm) is required for to achieve good surface cure and UVA (320-390 nm) is required to ensure good depth of cure.

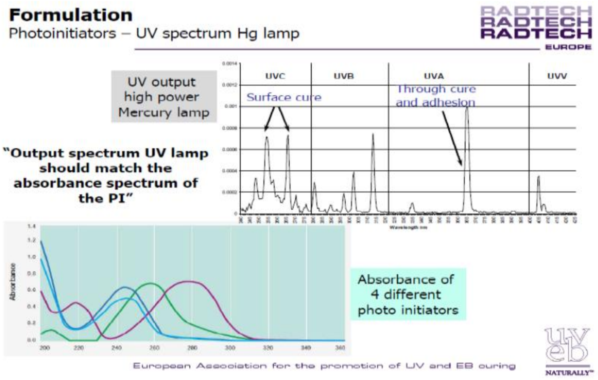


Figure 3: Spectral data of mercury based UV lamps

To overcome these deficiencies in the lack of surface cure when using UV LED lamps will require lengthy R&D work to develop new formulating strategies and possibly new raw materials, in particular, new photo initiators. Developments of new photo initiators, to match discreet, narrow band emission of UV LEDs at 385 nm, 395 nm or 405 nm take several years (5-10 years), particularly when taking into account the toxicological evaluations that are required for new chemicals as mentioned under 6B of the VDMA request.

Especially for processes which require a high speed to deliver a large volumes of products, more energy output from LEDs is needed than is currently available. Examples of this are in curing of inks and coating, as used in printing and packaging applications and also in non-curing applications such as disinfection. In this application, the UV power of the disinfection lamp is about 100-400 mW/cm^2 at output window. The power of commercially available 265 nm UV-LED (device size 3.5 mm^2) is lower compared to the Hg high pressure lamp. The light source on which these UV-LED are densely mounted in a flat, can emit only about 10% UV power of the device using Hg high pressure lamp. So the disinfection device using UV-LED is not practical because it results in much slower processing speed and/or in having longer processing area.

Similar justification is also used in the text and Annexes in the exemption requests of VDMA and VskE which are available through your website.

b) Please clarify what efforts are being made to develop Hg free alternatives (LED alternatives or other possible technologies) for the full application range of high pressure lamps or for a specific part thereof. Please provide details as to such initiatives, their timeframes and expected results.

In contrast to LED technology emitting in the visible region, UV LED technology is insufficiently mature. This is because the market for general lighting is many orders of magnitude larger than the UV applications market, thus resources in the lighting area are much higher. Due to the smaller size of the UV applications market, UV LED technology development is much slower and the costs of the devices are much higher than in the visible range.

The current efficiency of UV LED emitting in the UVA region is 20-30% with typical lifetimes of 10,000-20,000 hours but UV LEDS emitting in the UVC or UVB region have only a 1-2% efficiency with lifetimes of less than 1,000 hours. This makes UVC and UVB LEDs unsuitable for many applications. The expected timeline for the development work to overcome these limitation and achieve a secure supply chain is not less than 7-10 years, with market maturity at 15+ years.

6. Please provide an alternative proposal for the exemption wording, integrating the various thresholds related to aspects described in your answers to Questions 1, 2, 3 and 4.

   Answer of LightingEurope: We strongly encourage the consultant not to recommend any changes to the current wording of exemption 4f.

Please note that answers to these questions are to be published as part of the available information relevant for the stakeholder consultation to be carried out as part of the evaluation of this request. If your answers contain confidential information, please provide a version that can be made public along with a confidential version, in which proprietary information is clearly marked.