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Restriction of Hazardous Substances (RoHS) and Pico-powered Lighting Products

This Eco Note examines the chemical safety of pico-powered lighting products and describes the RoHS directive and other environmental regulations that address the issue of toxic substances in electronics and electronic waste.

Introduction

Pico-powered lighting products are generally a safe, superior alternative to fuel based lighting. Research by Lighting Global and others strongly suggests a wide variety of health, environmental, and economic benefits for people who use pico-powered lighting products instead of candles and kerosene lanterns. In order to better understand the market and its impacts, Lighting Global's Eco Design Notes series examines the benefits and the potential drawbacks of these technologies as more people buy and integrate pico-powered lighting into their everyday lives.

All electronic products contain a number of common components, and some of these may contain hazardous substances. Some types of electronic circuit boards and solar panels have lead-based solders, plastic enclosures and wire insulation may have flame retardants that are toxic when released into the environment, and many subcomponents can have heavy metal content. These substances can pose a health hazard to workers during the manufacturing process, some could conceivably cause hazardous exposure to customers who use the products, and all are a concern when the product fails and is disposed or recycled.

This Eco Design Note examines the issue of hazardous substances in the subcomponents typically found in a pico-powered lighting product. We use the European RoHS directive, a major environmental regulation of electronics, as a starting point. Although pico-powered lighting products are at present generally not required to be RoHS compliant, this may change in the future and is one useful way to explore the topic. Other environmental regulations are mentioned as well. Batteries are excluded from this discussion and treated separately in **Eco Design Note 1: Battery Toxicity and Eco Product Design**.

Chemical Safety

Most consumers expect that the products they buy are mechanically and electrically safe. Products should not overheat, catch fire, have sharp edges, or otherwise present a hazard during normal use.

In addition to mechanical and electrical safety, there is a growing awareness and expectation that products should be chemically safe as well. This means that products should not expose people to chemical hazards during normal daily use, and not release toxins into the environment when they are recycled or thrown away at the end of their useful life.

RoHS (Restriction of Hazardous Substances)

In order to address the issue of chemical safety and electronic waste, the European Union launched the RoHS directive in 2003 to limit the use of the following substances in electronic devices:

- **Lead (Pb)**
- **Mercury (Hg)**
- **Cadmium (Cd)**
- **Hexavalent Chromium (CrVI, Cr^{6+})**
- **Polybrominated biphenyl (PBB)**
- **Polybrominated diphenyl ether (PBDE)**

After it was published, the RoHS directive was adopted into law by EU member nations and in full effect by 2006. In 2011, RoHS was updated (recast) and a new directive, informally called RoHS 2, was published and adopted in full by January 2013. RoHS 2 expanded the types of product categories covered by the directive, further established specific exemptions, and set timelines for full implementation. It also changed the European CE marking scheme to now include RoHS compliance (Figure 1).

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Figure 1. The European CE mark indicates RoHS compliance

The EU RoHS directive covers products placed on the market in EU member nations – including imported products. The practical implications of the directive are more widespread, however, as product manufacturers and the electronics industry are moving away from the banned substances in order to maintain a single bill of materials for products sold on the international market.

How RoHS works

The EU RoHS directives set limits to the chemical concentration, by weight, of *homogenous* materials in the electronic device. This means that any single piece of the product (i.e. any piece of the assembly that can be mechanically separated) must meet the concentration limits. Insulation on wires, leads on circuit components, and any coatings and finishes (that could be scraped off) are typical examples.

The concentration limits are applied to products placed on the market for consumer use. They are not applied on the component level. The manufacturer of the final product is therefore responsible for achieving and documenting RoHS compliance. Component suppliers typically have evidence of compliance and provide this to the product manufacturer, who maintains a technical construction file for the product.

European Union member nations are responsible for implementing the RoHS directive. Each member drafts legislation to cover products that are placed on the market in their individual jurisdictions, which means that only products for sale in European countries with RoHS laws are *required* to be RoHS compliant. RoHS specifically exempts batteries from consideration, choosing instead to focus on the other subcomponents typically found in electronic devices. Batteries, which can contain large amounts of hazardous substances in relation to the rest of the subcomponents, are dealt with separately in the EU Battery Directive (2006/66/EC).

Solar Panels in pico-powered lighting products

RoHS guidelines call for an exemption of "*photovoltaic panels intended to be used in a system that is designed, assembled and installed by professionals for permanent use at a defined location to produce energy from solar light for public, commercial, industrial and residential applications*". This definition does not include solar panels used in pico-powered lighting products - these may be separate panels (portable separate) or panels that are integrated directly into the product.

Crystalline solar panels may contain lead used in wiring the cells. At end of life, this lead will enter the waste stream and can leach out of the panel structure. It is possible to use lead-free solders in the construction of the solar cell arrays, and some manufacturers of pico-powered lighting products do this already and have RoHS compliant PV modules. This is not, however, an industry standard and remains an area of potential improvement for the technology.

Cadmium telluride (CdTe) and some modules based on copper, indium, gallium, and selenium (CIS/CIGS) are thin film technologies that contain cadmium (for CIS/CIGS modules, cadmium-free alternatives exist). These PV module types are, however, currently less common in pico-powered lighting products due to the low cost of competing crystalline technologies.

China RoHS

The China RoHS regulation considers the same substances in RoHS but treats them differently. Electronic Information Products (EIP) are required to have labeling to identify the presence of controlled substances and an estimated time before the chemicals will leak out of the product. This Environment Friendly Use Period (EFUP) is then indicated with a symbol (Figure 2).

Figure 2. China RoHS Environment Friendly Use Periods (numbers indicate years)

A summary of additional regulations related to RoHS is given in Figure 3.

RoHS Restriction of Hazardous Substances
- Directive 2002/95/EC
- Full implementation in EU by 2006
- Lead (Pb), Mercury (Hg), Cadmium (Cd), Hexavalent Chromium (Cr^{6+}), Polybrominated Biphenyl (PBB), Polybrominated Diphenyl Ether (PBDE)
- Restricts the concentration of substances in all homogenous parts of an electronic product

RoHS 2 Recast of RoHS
- Directive 2011/65/EU
- Expanded implementation starts 2013, full adoption covers all electronics by 2019
- Same substances as RoHS
- Exempts professionally installed solar panels but not panels in consumer electronics

WEEE Waste Electric and Electronic Equipment
- WEEE Directive 2002/96/EC
- Sets collection, recycling, and recovery targets
- Same substances as RoHS
- 85% recovery by 2019

REACH Registration, Evaluation, Authorization, and Restriction of Chemicals
- Regulation (EC) No 1907/2006
- Substances of Very High Concern (SVHC)
- Lists substances, does not restrict
- 87 listed SVHC's in 2013
- Updated twice per year

China RoHS
- Labeling of Electronic Information Products (EIP)
- Lists Environment Friendly Use Period (EFUP)
- Same substances as RoHS
- Phase 2 bans substances in phones, printers

California RoHS
- Lead, Mercury, Cadmium, Hexavalent Chromium
- Covers a limited subset of electronic products

Figure 3. List of RoHS related regulations

Hazards from Toxic Substances

Many of the toxicological effects of RoHS and other substances are well known, while for others the negative health impacts are less certain. The negative health effects of heavy metals have been known for a long time, for example, while the health effects of additives used in plastics are not yet well understood and a subject of some debate. The exposure of people to toxins in manufactured products can be divided into three categories: manufacture, use, and disposal.

Manufacture

Manufacturing can present significant hazardous exposures to workers, and industry movement to less toxic materials has benefits throughout the manufacturing chain. A switch to lead free solders, for example, not only eliminates worker exposure to lead bearing solder pastes but also reduces exposures associated with the mining, processing, and transportation of lead. This is true of other hazardous substances as well, and while the elimination of these substances does not guarantee a safe manufacturing environment, it does help mitigate some health risks present in the factories where products are made.

Daily Use

In most circumstances, exposures to hazardous substances from pico-powered lighting products during normal daily use will be small. The primary exposure hazard would likely come from the plastic housing and cables. PVC wire insulation has phthalates used as plasticizers, and plastic housings might contain brominated flame-retardants. Some research suggests these chemicals leach out of the plastic during normal use and casual contact.[1] They are persistent in the environment and will bio-accumulate in the food chain. At present, the negative health effects from these substances, as present in dust particles released due to normal daily use, is a matter of debate and not likely to be of concern for pico-powered lighting products.

[1] "Why BFRs and PVC should be phased out of electronic devices" February 26, 2010 www.greenpeace.org

Disposal

Electronic waste is a major environmental concern for many parts of the developing world. Improper disposal allows hazardous substances to be released into the environment through gaseous emissions (as a byproduct of burning) or from chemical leaching (where toxins can contaminate the local soil or water supply). Uncontrolled disposal, prevalent in most parts of Africa, is likely the area of most concern for hazardous substances in pico-powered lighting products.

In one common example, copper metal from copper wire is often recovered by open air burning of bundles of wire. This removes the plastic insulation from the wires, but also exposes the people doing the recycling to the fumes from the burning. It releases toxins into the air, and residue from the ash contaminates the ground and can then leach into local water supplies when it rains.

Parts of Africa serve as major importer centers of second hand electronics and electronic waste. Ghana and Nigeria in Western Africa, in particular, appear to be major import hubs.[2] Some import electronics are intended for repair and reuse, but large portions are also non-operational and go directly into recycling and disposal.

Designing without Hazardous Substances

For most manufacturers, designing products without the use of hazardous substances begins by looking at the manufacturing procedures used by subcomponent vendors. In the printed circuit board (PCB) industry, RoHS compliance is also commonly referred to as "lead-free" and is a well-known concept. Most common electronic components (resistors, capacitors etc) have RoHS compliant versions as standard, and the PCB assembly process will very often include RoHS compliant lead-free solder and PCB finishes.

Lead-free soldering

Lead-free solders are common and available for most PCB manufacturing processes. Initially, lead-free solders offered some technical challenges due to higher temperature processing requirements and different solder joint performance and appearance. For the most part, these technical challenges have been overcome, and lead-free solders are accepted as equivalent if not superior alternatives to traditional lead based soldering practices.

Hand soldering remains one area where lead-based solders may still be in common use and lead-free solders present some manufacturing challenges. The higher temperature, decreased flow, and longer wetting time of lead-free solders requires a higher skill level for the hand soldering operation.[3] In most pico-powered lighting products, there are manufacturing steps that will require hand soldering. These include soldering wires from one board assembly to another or hand soldering plugs or connectors that are not compatible with automatic processes. It is possible, therefore, that a RoHS compliant circuit board will become part of a non-RoHS assembly in a final product. The amount of lead in the product will still be lower if the subcomponents are lead-free, and so RoHS compatibility is always a step in the right direction when looking at overall toxic concentrations.

Other RoHS subcomponents

While lead remains the most likely hazardous substance used in pico-powered lighting products, other RoHS controlled substances may be found in system subcomponents as listed in Figure 4. In most cases, non-toxic or lower toxicity options exist for all of these subcomponents and manufacturers can avoid RoHS substances without substantial product redesign and without incurring extra costs.

[2] "Where Are WEee in Africa? *Findings from the Basel Convention E-waste Africa Programme"* http://www.basel.int December 2011

[3] "Hand soldering and the impact of the RoHS directive" Dr. Paul Goodman, ERA Technology LTD www.era.co.uk/rfa.htm

Toxins in Pico-powered lighting products:
Where in the product are they found?

LEAD
- Lead based solders, SnPb alloys
- Plastics and stabilizers
- Paints and pigments
- Ceramics

CADMIUM
- Semiconductors (e.g. CdS photocells)
- Ceramics
- Solders
- Plastics
- Pigments

MERCURY
- Compact fluorescent lamps (CFL's)
- Curing agents

HEXAVALENT CHROMIUM
- Corrosion resistant coatings
- Passivation coatings
- Chrome plating
- Etchant for metalized plastics

PBB and PBDE
- Flame retardants in plastics
- Printed circuit boards
- Wire insulation

Figure 3. Hazardous substances in RoHS[4]

Testing products for hazardous substances

There are a number of ways to test products for hazardous substances. These can vary in complexity, accuracy, and cost, but all provide useful information to a manufacturer or testing agency investigating chemical content in a product or subassembly. These methods are primarily employed by organizations involved with RoHS type compliance efforts.

XRF screening (x-ray fluorescence) can be done using either a handheld 'gun' type device or bench top mounted station and are considered low cost methods. Handheld units in particular are useful for testing products remotely in a warehouse or distribution facility and can identify the presence of hazardous substances.

Chemical analysis can be performed when a higher level of accuracy is necessary. This typically includes crushing the component under investigation and sending the sample through successive steps to determine the presence and concentration of chemicals in the sample. Chemical analysis is more expensive and takes longer than XRF screening.

Summary

As pico-powered lighting products continue to improve in both performance and cost, additional considerations are likely to become increasingly important to the industry. Chemical safety in the manufacture, use, and disposal of these products will become part of the conversation. Pico-powered lighting products that are free of hazardous substances can use environmentally friendly manufacturing and design in product advertising and also position themselves to gain access to a wider international market where hazardous substances are restricted or outlawed altogether.

The pico-powered lighting industry places a premium on improving the lives and opportunities of the customers it serves. Eliminating hazardous substances from the products it sells is a natural extension of the moral underpinnings that make sustainable lights a valuable force for change.

[4] "Restricted Substance Requirements EU RoHS Directive (2011/65/EU)" Sunny Rai, February 2013 www.intertek.com/rohs