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Derleme /Review

LED Aydınlatma Sistemlerinin Çevre Kirliliğini Azaltmadaki Etkileri

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ÖZET: Günümüzde aydınlatma teknolojisi hızlı bir şekilde gelişmektedir. Bununla birlikte, enerji kaynaklarına olan ihtiyaç hızlı bir şekilde artmaktadır. Bilindiği üzere, dünyadaki enerji kaynakları sınırlıdır. Öte yandan enerji tüketimi de artmaktadır. Bu sebepten dolayı, enerji verimliliği ve tasarruflu enerji sistemleri gittikçe önem kazanmaktadır. Elektrik enerjisi kullanımı toplam enerji tüketiminde önemli bir paya sahiptir. Son yıllarda, temiz enerji kaynağı olarak adlandırılan LED aydınlatma teknolojisi bu alandaki en verimli aydınlatma sistemlerinden biridir. LED aydınlatma sistemleri yüksek verimliliğin yanında çevre şartları açısından temiz ve sağlıklı ışık kaynaklarıdır. LED aydınlatma sistemleri diğer aydınlatma kaynaklarında kullanılan civa, fosfor ve diğer zararlı maddeler gibi insan sağlığına zarar veren ağır metalleri içermezler. Ayrıca bu sistemler karbondioksit salınımı yapmazlar. Çalışmamızda, enerji verimliliği, LED aydınlatma sistemleri ve diğer aydınlatma sistemlerinin çevre üzerine olan etkileri incelenmiştir. Bu amaçla, veriler elde edilip, analizleri yapılmış ve sonuçlar tablolaştırılmıştır. Sonrasında sonuçlar detaylı bir şekilde açıklanmıştır.

Anahtar kelimeler: Enerji verimliliği, LED aydınlatması, Çevre etkileri. Temiz aydınlatma teknolojisi

Effects of LED Lighting Systems for Reducing the Environmental Pollution

ABSTRACT: At present, the lighting technology is evolving quite fast. However, the needs for the energy resources are increasing rapidly. As known in the world, energy resources are limited. On the other hand, the energy consumption is enhancing. Due to this reason, energy efficiencies and their energy saving systems are getting important. The electrical energy used in lighting systems has a significant share of total electricity consumption. In recent years, LED lighting technology, called clean energy, is one of the most efficient lighting systems in this field. Besides the high efficiency of LED lighting systems, these systems are clean and healthy light sources in terms of environmental conditions. LED luminaries commonly used for lighting do not contain heavy metals which are harmful to human health such as mercury, phosphorus and the other toxic substances. These systems also do not emit carbon dioxide. In our study, energy efficiencies and effects of LED light systems and the conventional lighting to the environment were investigated. In this case, the data obtained were analyzed and tabulated. After all, the results were explained in detail.

Key words: Energy efficiency, LED lighting, Environmental effects, Clean lighting technology

Introduction

Nowadays, the technology is evolving fast depending on increasing population and necessities in the world. The purpose of developing technologies is to make useful things to humanity and the environment. Also technological studies may have negative impacts on the environment. For this reason, environmental pollution is increased continuously.

The lighting system technology is one of branches in fast developing technologies. The lighting system should be considered in the aspect of the human health and environmental conditions. It is also performed in accordance with environmental standards. Otherwise, it causes to damage both human health and the environment. In addition, it causes light pollution. In this case, investigations have been proceeding on the prevention of the light pollution in the world. Especially, lightings of outdoors, streets, and skyscrapers which exceed limits are prohibited (Taylor, 2006).

The lighting systems should be harmless and clean in terms of health and environment. On this way, LED lighting systems are very important for the clean energy. While LED lighting systems do not contain harmful substances, they make energy savings and environment-friendly. Therefore, LED lighting systems are expected to replace with conventional lighting systems in the next 10 years (Morrow, 2008).

In this study, historical development of the conventional and LED lighting systems were presented. Subsequently, working principles of all lighting systems and contents of harmful substances in these systems were discussed.

Types of Light Sources

Incandescent lamp

The incandescent lamps are the oldest electrical lamps in commonly used. It was invented in 1870s by Joseph Swan in England, and by Thomas Edison in America. It has been evolved in time. Fig.1 denotes the parts of a typical incandescent lamp (Howell and Schroeder, 1927).

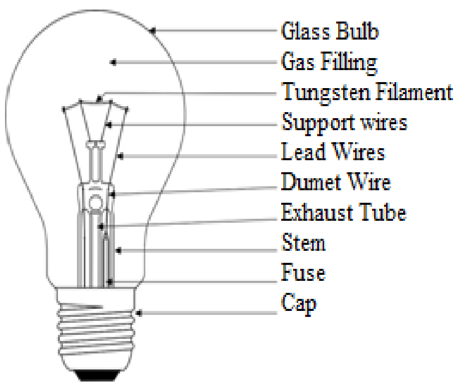

Figure 1. Incandescent lamp (Howell and Schroeder, 1927).

As working principle, the tungsten filament is heated to high temperature by an electric current passing through it, so the incandescent lamp emits light. The only problem of this lamp heat up a lot. The tungsten filament gets temperature level of about 2480 °C.

Incandescent lamps do not contain any hazardous substance but they have the lowest efficiency in conventional lightings. While major part of the energy consumption is released with heat (approximately 90 %), only 10 % of energy is converted to visible light by incandescent lamp (Anonymous, 2014a). Because the fact that energy efficiency is very important, it is not preferable for lighting aims.

Fluorescent lamp

It was invented in 1857 by Alexandre Becquerel, French physicist. During 1930's, the classic fluorescent lamp was developed for the general use. Fig. 2 denotes parts of a fluorescent lamp. The fluorescent lamp works by ionizing mercury vapor in a glass tube. A fluorescent lamp generates light from action in a hot gas of free electrons with atoms of mercury. Electrons are bumped up to higher energy stages and then fall back while emitting at two UV emission lines (185 nm and 254 nm). Then, created UV radiations are converted into visible light by UV excitation of a fluorescent coating on the glass envelope of the lamp (Anonymous, 1997).

Advantages of fluorescent lighting are energy efficient, low production cost, long life of tubes, good selection of desired color temperature, diffused light. Some disadvantages of the fluorescent lighting; the flicker can irritate to humans eye at high frequencies, diffused light is not good when you need a focusing, poorly and cheaply designed ballasts can create radio interference which disturb other electronics and create overheat. It is the most important point which includes mercury (according to standards approximately 5 mg) and phosphor elements. Especially, these heavy metals are harmful for the health, life and environment.

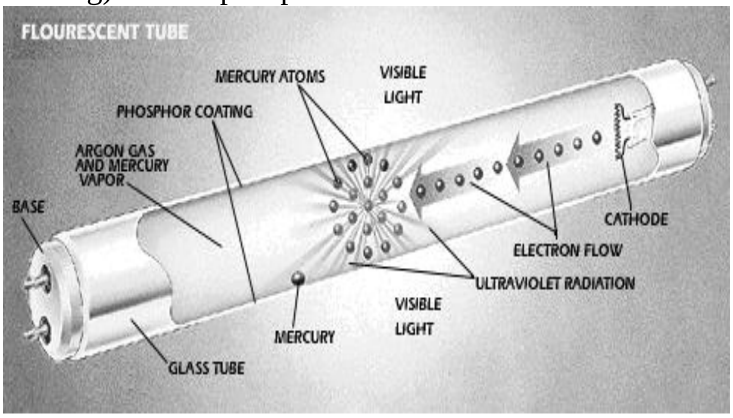

Figure 2. Fluorescent lamp (Dakto,2012)

Fluorescent Lamps and Phosphors: One of each blue, green and red fluorescent components is generally employed in modern triphosphorous tubes. The colour of fluorescent light depends on the phosphor types, chemical formulas. In this case, phosphor types, chemical formulas, and wavelength variations are given Table 1.

Table 1. Typical triphosphorous component materials and wavelengths (Anonymous, 2013).

Colour	Phosphor Type	Chemical Formula	Wavelength
Blue	Barium Aluminate (BAM)	$BaMg_2Al_{16}O_{27} : Eu^{2+}$	450nm
or	SrCaBaMg Chloroapatite	$(Sr,Ca,Ba,Mg)_5(PO_4)_3 Cl : Eu^{2+}$	453nm
Green	Calcium Tungstate (CAT)	$Ce_{0.65}Tb_{0.35}MgAl_{11}O_{19}$	543nm
or	Lanthanum Phosphate (LAP)	$LaPO_4 : Ce^{3+}Tb^{3+}$	544nm
Orange-Red	Yttrium Oxide (YOX)	$Y_2O_3 : Eu^{3+}$	611nm

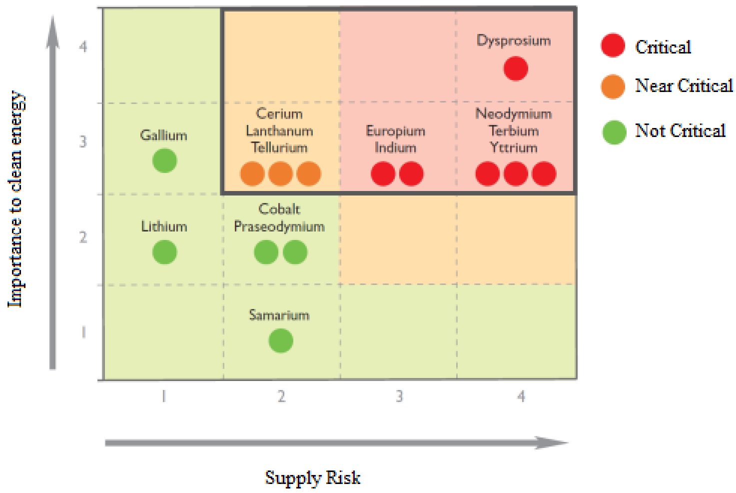

Figure 3. Rare Earth elements importance to clean energy and supply risk (Anonymous, 2011)

Table 2. Rare Earth Elements (Anonymous, 2013).

Material	Lighting Phosphors	Material	Lighting Phosphors
Lanthanum	●	Terbium	●
Cerium	●	Dysprosium	
Praseodymium		Erbium	
Neodymium		Yttrium	●
Samarium		Holmium	
Europium	●	Thulium	
Gadolinium		Lutetium	
Scandium		Ytterbium	

The fluorescent lamp includes triphosphorous component materials which are lanthanum, cerium, europium, terbium and yttrium. These are given in Table 2. The variation of the importance to clean energy with the supply risk is given in Fig. 3.

High pressure mercury vapor lamp

The high pressure mercury vapor lamp was developed in 1906 by P. Cooper Hewitt (Vrugt & Verwimp, 1980). The working principle; The voltage exists between the main and auxiliary electrodes when the lamp is connected to the supply. Then, these electrodes initiate the discharge and the light emission starts in tube. (Wilson, *et al.*, 1936). At normal temperatures, the mercury is available as a liquid in the tube. The tube conducts electricity. Then, the arc starts when the mercury is formed to be vaporized and ionized in the tube. Fig. 4 denotes parts of a high pressure mercury vapor lamp.

The starter is usually contained as internal within the mercury vapor lamp. Also it is used with fluorescent tubes. In the lamp operating, the auxiliary electrodes are used to facilitate starting. In addition to the mercury, there is an argon gas in the tube. When power is applied, there is sufficient voltage ionize the argon. Then, undersized arc is created between the main and the auxiliary electrodes. After that, the discharge initiates between the two main electrodes. Finally, the mercury is heated and then evaporated and the existing light occupies the tube. The mercury lamp gives full light after 4 -7 minutes.

If the mercury lamp resistance decreases, the lamp's current increases in the tube. So, this case shows that the mercury vapor lamp is a negative resistance device (Anonymous, 2014c.). The high pressure mercury vapor lamps which have the power of 50 to 2000 W can be found in markets today.

High pressure mercury vapor lighting has more energy efficiency than incandescent and most fluorescent systems at the outdoor lighting. The variety of colors is better than high pressure sodium lamps. Efficiency factor value is quite high. The mercury vapor lamps are resistant to vibration and impact. The combustion time of high pressure mercury vapor lighting is long. The mercury vapor lamps need auxiliary tools such as the ballasts. Their costs are more than others (Kaya, 2014).

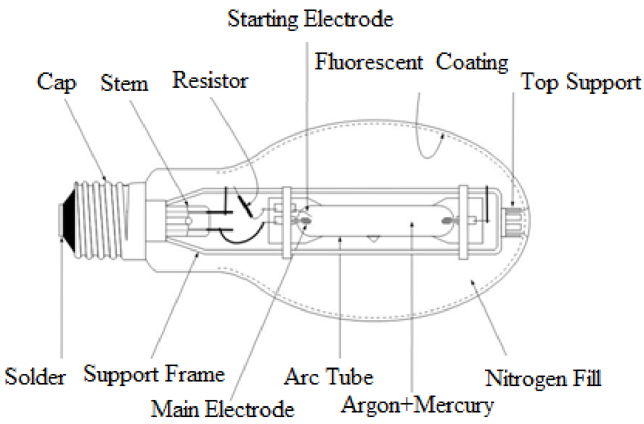

Figure 4. The high pressure mercury vapor lamp (Charles, 2007)

LED Lighting Systems

A Light emitting diode (LED) is essentially a pn junction diode. When carriers are injected across a forward-biased junction, it emits incoherent light. Most of the commercial LEDs are realized using a highly doped n and p junction (Schubert, 2006). Fig. 5 denotes parts of a power LED lamp.

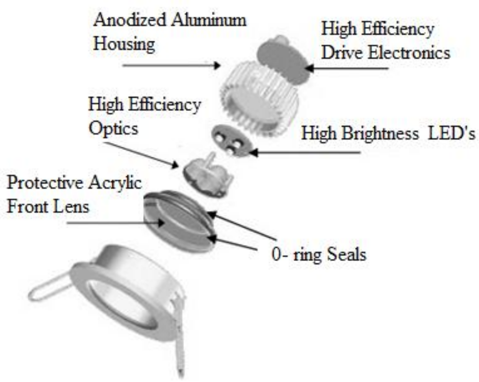

Figure 5. The LED lighting components.

LED lighting systems have a lot of advantages. These are luminous efficiency, colors, size, on/off time, dimming, cool light, slow failure, life time, focus, and environmentally friendly. Luminous Efficiency; LEDs emit more light per watt than other lighting systems. Colors; LEDs can emit light of an intended color without using any color filters as traditional lighting methods needed. Size; LEDs can be very small and are easily populated onto printed circuit boards. On/Off time; LEDs light up very quickly. A typical red indicator LED will achieve full brightness in under a microsecond. Dimming; LEDs can very easily be dimmed either by pulse-width modulation or lowering the forward current. Cool light; As comparison to many light sources, LEDs emit low heat in the form of IR that can cause damage to sensitive objects or fabrics. Slow failure; LEDs mostly fail by dimming over time rather than the abrupt failure of incandescent bulbs. Lifetime: LEDs can have 50.000-100.000 hours, relatively long useful life. Focus; the solid package of LEDs can be designed to focus its light. Environmentally friendly; LED's contain no mercury or other hazardous substances (Ohno, 2004).

On the other hand, LED lighting systems have some disadvantages. These are initial capital cost and junction temperature. On an initial capital cost basis, LEDs are more expensive than other lighting systems as a measure of the price per lumen. LED performance largely depends on the ambient temperature. Overheating of the LED package, eventually leads to device failure (Lim, *et al.*, 2011).

Table 3. Luminous efficiencies of different light sources (Coaton, 2001)

Light Source	Luminous efficiencies (lm/W)
Edison's first light bulb	1.4
Tungsten filament light bulb	15 – 20
Quartz halogen light bulbs	25 – 25
Fluorescent light tubes and compact bulbs	50 – 80
Mercury vapor light bulb	50 – 60
Metal halide light bulbs	80 – 125
Power LED	80 – 160

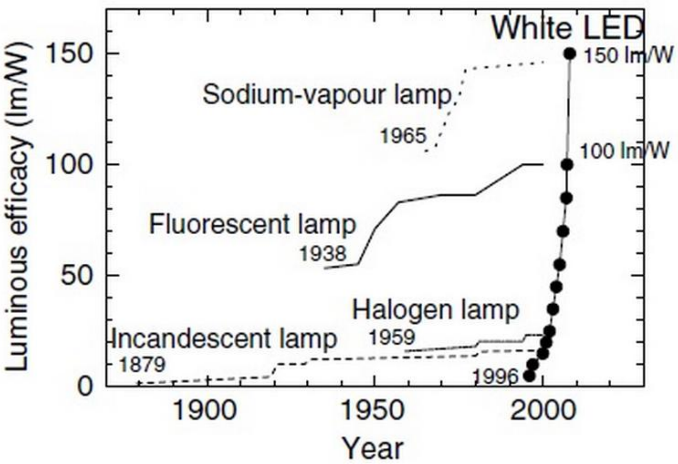

Figure 6. The variation of luminous efficiency of year (Zyga, 2010)

Power LED technology is the most efficient lighting technology. This is shown in Table 3. Researches show that LED lighting technology will grow up in next 10 years. In this case, the lighting technology doesn't contain mercury and the other toxic substances. The comparison of improvements on the luminous efficiency among LED, sodium vapor lamp, fluorescent lamp, incandescent lamp, halogen lamp at the interval of the years;1879-2025 is given in fig. 6.

The Mercury Substance and Hazards

Mercury is a naturally occurring element that is found in air, water and soil. The mercury is one of the heavy metals. It has been used worldwide along to many centuries for commercial (e.g., lighting) and medicinal purposes. Researches have shown that mercury can be a threat to the health of people and nature. When the mercury mixed with water, it is converted into methylmercury by bacteria and organisms. Methylmercury [CH_3Hg] is the most toxic form of mercury. Birds and mammals who eat fish that are more exposed to methylmercury than any other animals in water ecosystems.

Three forms of mercury

Mercury occurs in three basic forms: elemental (metallic), inorganic (mercuric chloride), and organic (methyl;ethyl) (Hailemariam, *et al.*, 2014).

First form is elemental mercury which is liquid at room temperature and includes less toxic than other forms. It has a high vapor pressure. If it heats, mercury evaporates and becomes highly toxic. Metallic mercury is lipophilic that is stored in fatty tissues.

Second form is inorganic mercury. In general, divalent mercuric salts are soluble in water. The high toxicity of mercuric ions can be explained by the high affinity to sulfhydryl groups of amino acids, which are building blocks for enzymes.

The last form is organic mercury compounds. The mercury is covalently bound to carbon. Methylmercury is most commonly found in the environment. It is converted from its inorganic form by a biological bacterial process. Organic mercury is the most dangerous form of mercury to human health and environment (Bose-O'Reilly, *et al.*, 2010).

Table 4. Overview of mercury exposure sources (Bose-O'Reilly, et al., 2010)

Mercury	Sources	Routes of exposure	Elimination	Toxicity
Elemental (metallic)	Artisanal gold mining Dental amalgams Crematoria Thermometers and other measuring devices Folk remedies Volcanoes Combustion Waste incineration Housing on former	Inhalation	Urine and feces	CNS Kidney Lungs Skin (acrodynia in children)

	tailings			
Inorganic (mercuric chloride)	Food grown in contaminated sites Thiomersal Cosmetics Folk medicine Lamps Photography	Ingestion Dermal	Urine	CNS Kidney Gastrointestinal tract Skin (acrodynia in children)
Organic (methyl; ethyl)	Fish Fungicides	Ingestion Parenteral Transplacental	Feces	CNS Cardiovascular

Health effects of mercury

The mercury has lots of effects on humans. These are given as follows;
(1)The neurotoxicity of mercury is devastating, especially for the central and peripheral nervous systems of children,
(2) Damage to brain functions,
(3) Damage to DNA and chromosomal,
(4) Allergic reactions, resulting in skin rashes, tiredness and headaches,
(5) Negative reproductive effects, birth defects and miscarriages
(6) Cardiovascular system – High blood pressure, altered heart rate, increase heart attack risk (Gad,2014).

Table 5. Comparison of methyl mercury limits (Anonymous, 2014b.)

Committee/ Council	Intake Dose	Levels corresponding to the intake dose	
		Hair	Blood
FAO/WHO Joint Expert Committee on Food Additives (JECFA)	1.6 μg/kg body weight Provisional Tolerable Weekly Intake (PTWI)	14 mg/kg 2 *μg/ gram corresponds approximat*	-
US EPA reference dose US National Research Council (NRC)	0.1 μg/kg body weight per day. OR 0.7 μg/kg body weight per week	*1 μg/ gram of hair*	*5.8 μg/L*

The importance of cleaning of lamp breaks which contain mercury:

CFLs and other fluorescent light bulbs contain a small amount of mercury sealed within the glass tubing. When a fluorescent bulb breaks in the home, some of this mercury is released as mercury vapor. During this time immediately following the break of a compact fluorescent light bulb, mercury gas concentrations near the bulb shards are between 200 and 800 g/m^3. The average 8-hour occupational exposure limit allowed by the US Occupational Safety and Health Administration is 100 g/m^3. To minimize exposure to mercury vapor, United States Environmental Protection Agency (EPA) recommends that residents should follow the cleanup and disposal steps described.

Before Clean up: Have people and pets leave the room. Air out the room for

5-10 minutes by opening a window or door to the outdoor environment. Shut off the central forced air heating/air-conditioning system, if you have one. Collect materials needed to clean up broken bulb: stiff paper or cardboard. Damp paper towels or disposable wet wipes (for hard surfaces); and a glass jar with a metal lid or a sealable plastic bag.

During Clean up: Do not use vacuum. Vacuuming is not recommended unless broken glass remains after all other clean up steps have been taken. Vacuuming could spread mercury-containing powder or mercury vapor. Be thorough in collecting broken glass and visible powder. Scoop up glass fragments and powder using stiff paper or cardboard. Use sticky tape, such as duct tape, to pick up any remaining small glass fragments and powder. Place the used tape in the glass jar or plastic bag. See detailed cleanup instructions for more information, and for differences in cleaning up hard surfaces versus carpeting or rugs. Place cleanup materials in a sealable container (EPA, 2014).

Results and Discussion

When the lighting luminaires analyzing, Light Emitted Diodes (LED) do not contain harmful heavy metals such as mercury and phosphorus. These heavy metals are very hazardous to human health and the environment. The fluorescent lamps, the mercury vapor bulbs, and the compact fluorescent lamps include heavy metals. When these lamps are broken, the mercury vapor and phosphorus are emitted to the environment. These are very dangerous for human health and the environment. When the mercury vapor is exposed, it causes damage to the central nervous system. At the same way, if someone gets into the lungs by inhalation of phosphorus, it can lead to cancer.

The mercury has never been vanished at the nature. Florescent lamp includes 0.005 gram mercury according to standarts. While 0.001 gram mercury can pollute approximately 1000 liter water, one florescent lamp can be pollute approximately 5000 liter when it is broken. Furthermore the fluorescent lamps also emit UV rays which are damage to our skin and eye health.

LED lighting technology does not have the harmful effects on human health and the environment because of the fact that its structure does not contain heavy metals. The LED lighting technology has more efficiency than other lighting technologies. For this reason, the importance of LED lighting technology has been a rising trend in the last 10 years.

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