Environmental Impact for Replacement of Incandescent Lamps by Compact Fluorescent Lamps

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ABSTRACT

The world replacement of incandescent lamps by compact fluorescent lamps has motivated us to carry out the present work whose objective is to establish indicators of the favorable and unfavorable situations that it generates. This work is based on a comparison between both types of lamps by energetic analysis first, and by an economic and environmental analysis later on. The scope of analysis and indicators obtained has been developed worldwide. The conclusion is an important advantage of energy saving lamps from energy and economic point of view. Nevertheless in the environmental aspect, although the same ones derive in a smaller emission of carbon dioxide, its disposal without a suitable treatment in specialized companies and specifically authorized by the competent authority for this activity, will generate, by mercury presence, a potencial contamination of drinking water estimated at 3 km^3 per year on the planet.

Keywords: incandescent lamps, compact fluorescent lamps, energy and cost savings, carbon dioxide emissions, mercury, drinking water contamination

1. INTRODUCTION

While energy-saving lamps or compact fluorescent lamps, usually identified with the initials CFL (compact fluorescent lamp), have a significantly lower amount of mercury than the traditional fluorescent tubes and are harmless during their lifetime, become waste dangerous when it runs out this life, or when they should be removed and dumped as waste in landfills for municipal solid waste. Hazardous or special waste under the Environment Programme of the UN in 1985 are waste (solid, sludge, liquid and gas content) which because of their chemical activity or toxic, corrosive, or other characteristics, causes or may cause danger to health or the environment, either alone or when it makes contact with another residue [1].

As for incandescents lamps, although it is known that the same should be replaced for the benefit of environment, in terms of reducing carbon dioxide emission, the main greenhouse gas responsible of climate change and, when they deplete their life, they become harmless waste from the point of view of harmful pollutants, which raises concerns about a more sustainable alternative.

For health problems associated with the presence of hazardous waste it is necessary to establish a cause and effect relationship between pollution and effects on the health for what it becomes necessary to study the routes of exposure.

According to the Agency for Toxic Substances and Disease Registry Department of Public Health of the U.S. ATSDR [2] the exposure route is composed of five elements: pollution sources, means of transport of pollutants, exposure points, respiratory and dermal exposure and recipient population.

Among the dangerous pollutants of recognized toxicity that they might find in the places of final disposition of solid residues we can distinguish pesticides, solvents, infectious residues and metals. Among the above mentioned we can distinguish fundamentally arsenic, beryllium, cadmium, chrome, antimony, barium, lead, mercury, silver and talio, which are priority metals in the list of the EPA [3].

At the time of disposal, fluorescent lamps must be managed as dangerous residues due to its mercury content. The materials of the lamps are inside a closed system, for which its suitable use does not represent risks or impacts on the environment or the health. The above mentioned materials get in contact with the environment only in case of breakage or destruction, being the principal risk the release of the mercury.

Mercury causes a wide range of systemic effects in humans (kidneys, liver, stomach, intestine, lungs and a special sensibility of the nervous system), though they change with the chemical form. The microorganisms turn the inorganic mercury in methylmercury, a chemical very toxic, persistent form and bioaccumulative chemical, and that in addition is easily absorbed in the gastrointestinal human tract [4]. Also it acts as an inhibiting agent of the enzymatical activity and can provoke the appearance of foetal malformations. Likewise it is toxic for the raptors and other varieties of the wild fauna. Also it is responsible for injuries in the plants and for reducing their growth [5].

Waste fluorescent lamps should be considered in terms of national law governing hazardous waste. Specifically, the heavy metal mercury is considered by hazardous waste law as waste containing mercury as constituent and should be controlled. As specified in Annex I of the Law 24051 of hazardous waste as Y) 29. Mercury. Mercury compounds.

2. OBJECTIVE

Introduce a study taking into consideration the environmental ethical issue, which is concerned about the attitude of people towards other living beings and to the natural environment [6].

Moreover, the study seeks the purpose of preventing pollution, a term that describes the production of strategies and technologies that result in the elimination or reduction of waste streams. EPA defines pollution prevention as "the use of materials or methods that reduce or eliminate the creation of pollutants or wastes at source. This includes methods to reduce the use of hazardous materials, energy, water or other resources and procedures that protect natural resources through conservation or more efficient use" [7].

To conduct a comparative study between fluorescent compact lamps and incandescent lamps from the energy standpoint.

Depending on the energetic analysis to establish an economic and environmental study that clearly visualizes the differences that the characteristics of every type of lamps offer.

To determine indicators or parameters which allow generating a discussion as for the advantages and disadvantages of the use of both types of lamps.

To conduct a study for the alternatives of CFL treatment considering its danger when they turn into residues.

3. DEVELOPMENT

Depending on the comparison indicated in the Table 1 there will be realized energetic, economic and environmental analysis.

Title	CFL Lamp	Incandescent Lamp
Efficiency (lumen/watt)	60	12
Useful life (hours)	8000	1000
Acquisition cost (USD)	5	0,50

Table 1 - Comparison of compact fluorescent lamps and incandescent lamps

Energetic analysis

In conformity with Table 1, for example, an incandescent lamp of 75 watts is equivalent to a CFL lamp of 15 watts considering both luminous flow efficiency. The electric power consumption, bearing in mind that we needs eight incandescent lamps to reach the useful life of a CFL lamp, you can observe in Table 2.

Title	CFL Lamp	Incandescent Lamp
Electric power consumption (kWh)	120	600

Table 2 - Electric power consumption during the useful life of a CFL lamp

Economic analysis

Considering a variable cost of electric power of 0,075 USD/kWh the costs for both lamp are observed in Table 3. During the useful life of a low consumption lamp eight incandescent lamps must be bought. So acquisition cost of every lamp also observes in Table 3.

Costs (USD)	CFL Lamp	Incandescent Lamp
Electric power	9	45
Acquisition	5	4
Total	14	49

Table 3 - Costs during the useful life of a CFL lamp

During the useful life of a CFL lamp, the economic saving is 70 %. Though the initial cost of CFL lamp is approximately ten times major that incandescent ones, along its useful life, the saving is considerably top. Supposing that both lamps are ignited for six daily hours the CFL lamp amortizes its cost after a semester.

Environmental analysis

The favorable aspect of the use of fluorescent lamps in replacement of incandescent ones is the important reduction in carbon dioxide emission. Considering an emission factor of 0,547 ton CO_2/MWh and taking the values of energy power consumption presented in Table 2, can be observed the equivalent quantity of carbon dioxide emission in Table 4.

Title	CFL Lamp	Incandescent Lamp
Carbon dioxide emission (kg)	65,64	328,20

Table 4 - Carbon dioxide emission during the useful life of a CFL lamp

In agreement to the values of Table 4 the decrease of carbon dioxide emission for the replacement of a CFL lamp during its useful life ensues 262,5 kg. It represents 80 %.

The unfavorable aspect of CFL lamps is the presence of mercury that, though during his useful life it does not represent any risk, whether it is when they are rejected and thrown to the dumps liberating the present mercury when the same ones break being able to contaminate the underground waters for percolation.

The environmental agency of United States (EPA) catalogued already in the decade of the 1980s to lamps containing mercury as a hazardous waste. This same body demonstrated that its disposal in landfills does not guarantee the contamination of groundwater from leachate [8]. Mercury is extremely dangerous because it has bioaccumulative effects on the food chain which is indispensable to take precautions.

The qualit criteria for drinking water [9] and the internal primary regulations of the United States [10] for mercury you can observe in Table 5.

Metal	Guidelines for Drinking Water Quality WHO, 1996 (mg/L)	Internal Primary Regulations EPA, 2000 (mg/L)
Mercury	0,001	0,002

Table 5 - Qualit criteria for the drinking water

Considering the content of mercury in a fluorescent lamp is approximately 5 mg the potential pollution of the same one for drinkable water observes in Table 6.

Metal	Drinking Water – Guides WHO (Liters)	Internal Primary Regulations EPA (Liters)
Mercury	5000	2500

Table 6 - Potential pollution of drinking water by a CFL lamp

Adopting the specifications of the EPA and the quantity of saved carbon dioxide the resultant relation is 9,5238 liters of water per kilogram of carbon dioxide.

4. CONCLUSIONS

Despite the small amount of mercury deposited in each low-power lamp, its massive use, due to its lower consumption and emissions and extended use, presents a different environmental risk as that from the incandescent lamps, whose little efficiency makes mandatory their progressive substitution. However this action contributes to pollution with mercury in the water and the environment, if CFL lamps are not discarded selectively around the world.

Despite its obvius advantages in duration, cost savings and energy savings, the use of mercury poses problems, foreseeing that millions of CFL lamps with an average of 5 mg inside, will be disposed incorrectly and could get into contact with people and animals by inhalation, contact or ingestion.

Despite the scientific certainty that a momentary exposure to a broken CFL bulb while it is cleaned, put in a bag and disposed selectively, does not constitute a risk to health, global technology expansion increases the risk, particularly in countries and socio-economic environments where the application of regulations will have less real monitoring by a less informed population.

On the other hand, this pollution is added to the great pollution generated by the traditional fluorescent residual tubes [11] which contain within them seven times more mercury than energy saving lamps.

Whereas the cost of treatment in specialized companies specifically authorized by the competent authority for this activity is approximately 0,25 USD/kg and that fluorescent energy saving lamps have a weight of 120 grams (taking into account a 15 W lamp) the cost is only 0.03 USD per each lamp. This means that the treatment cost represents only 0.6% of the initial cost of the lamp, with which it would be economically feasible its proper disposal instead of throwing them into a landfill destined for urban solid waste. Here the difficulty focuses on the limited availability of specialized companies, especially in developing and emerging countries.

Artificial lighting is responsible for 19% of global electricity consumption equivalent to 2.4 per cent of world consumption of all primary energy used. By 70% of the energy used for artificial lighting is consumed by incandescent lamps which represent approximately 1.7% of world consumption of all primary energy.

Taking into account that 80% of global primary energy comes from the combustion of fossil fuels [12] we can consider that approximately 1.3% of global primary energy by fossil fuels is used to power incandescent lamps.

The approximate global emission of carbon dioxide is 30 gigatons per year [13] so 390 gigakilograms of carbon dioxide are issued annually to keep incandescent lamps lit per year. By replacing them, as it has been previously calculated, a saving of 80% in carbon dioxide emissions is an annual global saving of 312 gigakilograms.

The electricity saved, in accordance with the adopted emission factor of 0,547 ton CO_2/MWh, represents an energy saving of 570 terawatt-hours per year.

Whereas the relationship between 9.5238 litres of potentially contaminable drinking water per each kilogram of saved carbon dioxide, the possibility of mercury contamination is approximately 3 annual teralitros, meaning 3 annual km^3 of drinking water.

In the light of these results, as drinking water is an absolutely essential natural resource for the life of human beings, and that also only 1% of water present in the world can be seen as drinking water, it seems that the use of energy saving lamps might jeopardize this fundamental natural source.

On the other hand, a reduction of this greenhouse gas emission seems important in absolute value, it does not seem to be so in relative form. If an adequate provision of CFL replacement lamps is not provided, it could be a wrong path in the fight against greenhouse gasses and climate change.

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