ISSN 0236-2945

LIGHT & ENGINEERING

Volume 12, Number 4, 2004

Znack Publishing House, Moscow

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VOLUME 12 **NUMBER 4** **2004**

LIGHT & ENGINEERING
(SVETOTEKHNIKA)

Light & Engineering
Vol. 12, No. 4, pp. 60—65, 2004

Svetotekhnika
No. 6, 2004, pp. 22—25

WASTE DISPOSAL IMPACT FROM STREET LIGHTING

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1. Introduction

During their life cycle street lighting installations generate waste that may originate from the following processes:

- components which due to their nature undergo fortuitous failures and should be substituted.
- massive and programmed substitutions of components for technical and economic reasons (reduced performance service means they must be replaced periodically).
- renewal of the installations for technological updating.
- dismantling of the installations at the end of their useful and economic life.

Products which usually constitute waste in street lighting can be classified in three groups according to their impact (*Iribarne, 2001*) [1]:

- Low impact products: waste made up of electrical materials such as insulators and copper conductors, which in turn are highly recyclable and reusable in the market. Refractors of luminaire optics are another example. They are made of borosilicate glass and are not accepted in glass recycling processes. If such refractors do not show fractures, they can be given to companies that repair them for their future use.
- Intermediate impact products: elements such as electromagnetic ballasts which can be disassembled separating their components: polyester, copper coil, iron nucleus etc. for melting down or use as a mixture in civil construction. Capacitors would also be included in this group. They contain metalized polypropylene and their waste could be used in mixtures for the manufacture of wood-like materials.
- Considerable impact products: fluorescent and discharge lamps with mercury content.

2. Lamps as waste

More and more discharge lamps of the high mercury vapor (HPM) kind and of high pressure sodium (HPS), both of them containing mercury, are being used in street lighting installations. Data for the average content of mercury (Hg) per unit of weight is indicated in table 1 (*ELCFDL. 1997*) [2].

Table 1

Average mercury contents per lamp type

(Data from European Lighting Companies Federation [2])

Lamp type	Average amount of mercury [mg]
Linear Fluorescent	15
Compact Fluorescent	5
High pressure mercury HPM	30
Metal halide	30
High pressure sodium HPS	25
Low pressure sodium	—
Incandescent	—

If discharge lamps contain mercury, a toxic and polluting substance, why are they still used? The answer is that the presence of mercury in discharge lamps is essential for the light generation process and it is justified through its greater efficiency as compared with other alternatives such as incandescent lamps without mercury.

If in the European Union the quantity of light generated by discharge lamps (efficiency = =76 lm/W) was to be replaced by incandescent lamps (12.8 lm/W), the additional demand of energy would be 670 million MWh per year, which would be equivalent to some 205 million additional tons of coal in conventional thermal power stations with an emission of 675 million tons of CO_2 [2]. As coal contains 0.1 ppm (parts per million) *Siedel I (1992)* [3] of mercury, additional consumption would generate 20.5 tons of mercury per year, apart from sulphur dioxide (SO_2), nitrogen oxide (NO) *ATSDR (2004)* [4], heat losses and additional ash, which could have even greater environmental impact.

The mercury contained in the bulbs of discharge lamps does not represent any risk when the lamps are working. The problem occurs when the bulb (glass bulb in compact or linear fluorescent lamps) is broken as the lamp is disposed when its useful life is exhausted or due to premature failures. The mercury released comes into contact with the environment generating an ecological impact. Although mercury is present in nature, some of its concentrations can affect health, causing damage to the kidneys, the brain and to the fetus in gestation.

Mercury is liquid at room temperature and soluble in water at 20°C in concentrations of 60 mg/litre. The recommended content limit in drinking water is Img/litre, but 114 ng/litre ($n = 10^{-9}$) can affect health. One Kg of Mercury can in theory contaminate 1 000 000 m^3 of water [5].

People can be exposed to metallic mercury when glass thermometers or other devices containing mercury are broken or through the ingestion of contaminated fish. The Agency for Toxic Substances and Disease Registry, Department of Health and Human Service U.S. has established minimum levels of risk for the mercury methyl, which is the most common organic form of mercury when fish is consumed. The level is 0.3 micrograms per kilogram of body weight per day *(Daly K.,2000)* [6].

3. Generated Waste

A statistical study of maintenance operations carried out during a period of six years (92–98) [7] in lighting installations indicates that half of them are due to breakdown (corrective) maintenance operations of repairing. Of these, 72% is accounted for by maintenance operations over the street light units, as shown in table 2. Of this 72%, 54% in turn is accounted for by lamp failures (burnouts) as indicated in fig. 1. These high percentages show that in a street lighting installation the lamp is the component most likely to fail.

Based on the premise that the quality of the lighting service depends on values conveniently pre-established, we can estimate the number of lamps containing mercury that will be annually eliminated in a city to maintain quality service.

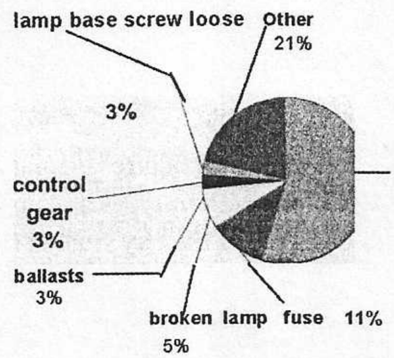

Fig. 1. Percentage of breakdown maintenance activities in street lights units [7]

Table 2

Distribution of maintenance, preventive programmed and breakdown operations according to population demand [7]

Maintenance activities

Preventive maintenance	50%	–	
Breakdown maintenance	50%	street light units	72%
		switchboards	25%
		electric lines	3%
Total	100%		100%

The annual number of lamps eliminated will also depend on the maintenance policy used. This number can be estimated from statistical data taking into account the number of lamp replacements due to failures (spot lamp replacement or breakdown maintenance only). If also a policy of programmed group lamp replacements (necessary because of the performance characteristic of discharge lamps) is applied, this additional number has to be added.

Table 3 indicates the percentage of annual lamp failures found sorted by type and lamp power based on a survey carried out in a city of Spain [8], where a spot lamp replacement plus a group lamp replacement every 3 year maintenance policy was applied. A medium value of 18.6% and 8.7 for Mercury and Sodium lamps respectively was observed. Such percentages are expected to be higher only if a spot lamp policy is applied.

According to table 3, once the amount and type of lamps installed in a city is known, it is possible to estimate the annual consumption from maintenance in order to keep good quality service.

Table 3

Percentage of annual failures annually accumulated for different types and power of lamps observed in the city studied [8]

Lamp type	High pressure mercury				
Watts %	80	125	250	400	aver.
annual lamp mortality	30.1	23.6	15.2	8.1	18.6
Lamp type	High pressure Sodio				
Watts %	70	150	250	400	aver.
annual lamp mortality	6.4	10	3.8	14.4	8.7

The city of Rosario, Argentina, is analyzed as an example. Its population of lamps following *(Deco, Casañas, 2002)* [9] is shown in table 4.

The weight in mercury generated annually only by spot replacements is 295.6 g/year. If the annual amount of lamps from a 4 year group replacement period for high pressure sodium and the amount of lamps from a 3 year group replacement period for high pressure mercury is added, the mercury weight would be 824 g/year.

In 25 years, the period that can be considered for the life cycle of street lighting installation, the accumulated mercury would be 20.6 kg. Without due care, such material ca may drain into drinking water sources.

Table 4

Lamp population in Rosario, Argentina [9] and estimation due to annual mercury weight replacements

Lamp type	Street light units	% annual lamp changes	Annual lamp changes	Mercury amount [g]
Incandescent	2.051			0
Tungsten halog.	45			0
HPM	18.134	18.6	3.773	113.2
Metal halide	2.132	18.6	397	64
Linear Flourec.	914	18.6	170	2.5
HPS	53.272	8.7	4.635	115.8
Total	76.548			295.6

4. International recommendations

Even though there exists some knowledge about the risk that mercury represents, there is not yet a single criterion as regards the measures to be taken. At the present time, the known methods of lamp elimination are:

- uncontrolled disposal to landfills;
- controlled disposal in deposits;
- uncontrolled incineration;
- controlled incineration;
- recycling.

The uncontrolled lamp disposal in landfills has the risk of mercury drain reaching and contaminating drinking water sources. Controlled lamp disposal or safe storage of the quartz tube when possible only concentrates and defers the problem.

Uncontrolled lamp incineration releases up to 90% of the mercury lamps contain unless the incinerators have filter emission controls. A survey carried out in Sweden *(Begley K./Linderso T., 1991)* [10], indicates that the controlled incineration filtering the emissions would capture 95% of mercury present in smoke but its subsequent controlled dump in a municipal landfill would again involve a problem due to the mercury concentration in the ashes.

Until low or nil mercury content lamps are developed, recycling is the most secure method among those already indicated.

Since January 2000 the U.S. Environmental Protection Agency classifies lamps containing mercury as universal waste with the goal of reducing the amount of lamps in municipal landfills and incinerators, promoting recycling or deposit in hazardous waste landfills [6].

The UE environmental legislation in its 91/156/CE and 91/686/CE guidelines considers the waste management concept. If discharge lamps are waste, selective gathering and adequate treatment could be applied. In Spain and in different communities there is a law to regulate waste following the CE guidelines. In Barcelona in Catalonia, the waste regulating law 6/1993 sets selective gathering centers in municipalities with over 5,000 inhabitants where, among other products, fluorescent and mercury vapor lamps will be collected *(ICAEN, 1998)* [11] *San Martin et al., 1999)* [12].

5. Recycling Costs

The Centre de Tractament i Reciclatge de Piles i Fluorescents *(R.F. PROCES, S.A., 1999)* [13] in Catalonia is in charge of gathering and eliminating fluorescent and discharge lamps. The cost for large lamp consumers such as municipal local governments or lighting maintenance companies is 0.6 €/kg (3/1999) with a minimum accumulated of 1.000 kg. For an average weight of 200 g per discharge lamp, the cost per lamp would be approximately 0.12 €. This cost is likely to be partly financed by the local authorities.

According to EPA (Environmental Protection Agency) recycling a 40W T12 fluorescent tubular lamp, costs 0.47 € [6] which represents 25% of the lamp cost.

Even though the actual cost of recycling lamps is high compared with the possible value from materials resulting from recycling process *(ELCF, 1998)* [14], it is not significant compared to the cost of the lamp itself, and the largest benefit obtained from applying recycling policies that justify this activity is the reduction of the environmental impact in recovering mercury.

It is assumed in this analysis that the recycling process is a controlled process that separates toxic components for subsequent reutilization or controlled elimination, and that the environmental benefits of such technology outweigh those used to eliminate waste in an uncontrolled way.

A more complex analysis should consider the cost/benefit relationship in the life cycle of lighting installation. The recycling cost per lamp can be incorporated as an additional lamp cost. However, the implicit cost of the environmental impact is not easy to evaluate in economic terms.

6. Recycling process

The present recycling process in use briefly presents the following steps [12].

- Reception of lamps
- Destruction of lamps in a controlled and isolated atmosphere
  - Punching of one of the metallic bases to eliminate the vacuum inside the tube.
  - Removal of the metallic bases; for which the ends of the glass tube are heated with a propane flame and abruptly cooled with a drop of water, which makes the glass break at that point causing the separation of both heads.
  - Elimination of the fluorescent powder stored in the tube inner walls through scraping by means of a brush and compressed air. The powder is collected by means of a cyclone and the air that comes out passes through a net bag and active carbon filters before it is expelled to the atmosphere. *(Departament de Medi Ambient, Junta de Residues, 2001)* [15]
- Application of separation techniques by means of aspiration or dragging of liquids.
- Canalization of fluid toxic products to absorption systems.
- Separation of toxic product from system absorption in ovens.
  - Distillation of mercury mixed in the fluorescent powder and metallic parts. The distillation process is tested in an inert chamber with nitrogen, the chamber is electrically heated to 550–600°C. Next, gases pass through a combustion chamber at about 800°C to burn organic components which are still found there.
  - Finally, heat exchangers in series cool gases at about 2°C to condensate mercury and water, which are separated by centrifugation and sedimentation since their density is high. Gases are filtered in an active carbon filter before they are expelled into the atmosphere.

- Distribution of the resulting products are to be re-utilized or eliminated as inert matter or non-recycling toxic products.

The main steps of the process are indicated in fig. 2.

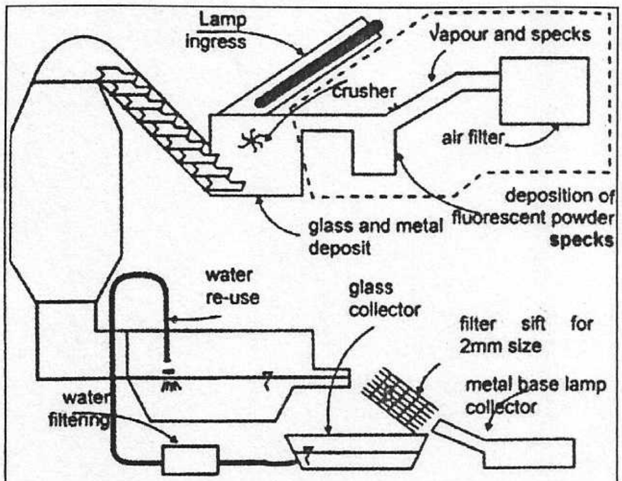

Fig. 2. Mercury lamp recycling process

There are several companies that offer the recycling service or the necessary equipment for lamp and battery recycling plants. In any case, it is necessary to handle a large volume of components to be recycled. For that reason large and small municipalities should unify waste management policies in order to face the expenses that a recycling system involves.

7. Street lighting management

Safe waste management does not eliminate all possible environmental impact. In a life cycle assessment study, about 90% of the effect of discharge lamps on the environment is due to energy consumption during use; 8% is accounted for by materials from production and distribution phases, while 2% is from the waste disposal stage.

The environmental impact problem should be considered not only at the end of a lamp's useful life or in case of failure but also in a global approach where design, use and maintenance should be efficient, economical and minimized to actual needs, and finally safely disposed of.

Municipalities should avoid uncontrolled disposal and plan the most adequate waste management policy according to prevailing circumstances and project scale. As this will imply costs of:

- transport;
- manipulation;
- storing and processing,

street lighting management should consider these expenses in the budget.

The possible alternatives are:

- store
- transport waste to a controlled disposal.
- transport waste to a recycling plant. Although the latter would be the most effective solution, it must be said that there are many geographic areas without plants, or if they do have them, their own capacity may be not sufficient for the lamp total volume.

Transient storage may at first appear the easiest solution, but in the long run this does not completely guarantee the control and stability of the stored waste. To avoid a great storage volume, it is advisable to crush the lamps always trying to prevent waste scattering during the process. The same precautions should be taken in transport operations.

8. Conclusions

There is not a unique nor a definite solution when planning the management policy to be adopted regarding the destination of lighting waste. Recycling is the trend in developing countries as well as the reduction of mercury content in lamps. The adoption of a recycling policy will depend on its cost, taking into account environmental benefits. In the case of adopting recycling, it is very important to develop the appropriate technology to face this problem.

This paper only refers to mercury as the most problematic element, but its hypothetical total removal would still leave other problems without solution.

9. Acknowledgements

The authors wish to thank to the Universidad Nacional de Tucumán, CONICET, and Universitat Politècnica de Catalunya, Barcelona, Spain for financial support.

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