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COMPARISON OF MERCURY DISTRIBUTION BETWEEN THE TYPES OF SPENT FLUORESCENT LAMP

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Spent fluorescent lamps(SFLs) such as linear type lamp, compact type lamp and U-type lamp are used to estimate mercury distribution in the components of lamps. Determination of mercury concentration in the components of spent fluorescent lamp is performed by the DMA method. Mercury concentration in the components of spent fluorescent lamp can be varied with the manufactures of lamp. Mercury portion in phosphor powder and glass from any types of spent fluorescent lamp is estimated to be higher than 99% by the analysis of mercury distribution. Through mercury distribution in the components for SFLs, the mercury concentration in phosphor powder is much higher than that in other components regardless of the type of lamp. Hence, it is desirable that phosphor powder of spent fluorescent lamps should be controlled separately and safely.

Keywords: spent fluorescent lamp, types, phosphor powder, mercury distribution

1. Introduction

Spent fluorescent lamps(SFLs) will be required to manage separately in Korea because SFLs have been managed as household wastes even though SFLs contain toxic material such as mercury. The aim of management of SFLs is to reduce the release of mercury into the environment and to reuse glass, metals and other components of SFLs. In 2000, the recycling demonstration of spent fluorescent lamp was started in Seoul metropolitan area and extended producer responsibility (EPR) system was applied to spent fluorescent lamps to recycle them from 2004. There are several different kinds of fluorescent lamps, including linear lamps, U- type lamps, and compact fluorescent lamps (CFLs). The amount of mercury in a fluorescent lamp varies with the type of lamp, manufacture and date of manufacture, but typically ranges between 5 milligrams and 25 milligrams[1].

According to Ministry of Environment in Korea, about 133 million lamps were generated in 2012 and U-type lamps were generated about 39.9 million tubes among SFLs. The portions of linear lamps, U-type lamps, and compact fluorescent lamps(CFLs) among SFLs were 55%, 30%, and 10%, respectively. About 12.0 million of U-type lamps were recycled, while about 38 million of spent fluorescent lamps were recycled in 2012. Recycling rate of U-type lamps in Korea is approximately 30.0% but about 70% of U-type lamps are not managed properly. Hence, discarded lamps among U-type lamps might release approximately 0.6 to 0.9 tons of mercury per year into the environment[1,2].

In 2013, UNEP(United Nations Environment Programme) tried to be effective to control mercury emission by 'The Minamata convention on Mercury' in Kumamoto, Japan. MEBA(Mercury Export Ban Act) was activated from 2013 in USA to control the export of mercury from US to other countries. According to Universal Act in USA, SFLs can be controlled to recycle and manage safely and merchandise containing mercury has been prohibited to produce except fluorescent lamp. In USEPA, high mercury wastes such as PDP, battery, and lamp are classified by total mercury content which should be greater than 260 mg/kg[3-5]. MRT System developed by Lumalampan, Sweden was separated mercury from SFL by distillation operation since 1979. In Sweden, reverse route collection system has been activated to improve the collection of SFLs which has been controlled by EPR(Extended Producer Responsibility) system since 2001. In Austria, more than 30 companies are involved in recycling of SFL to recycle glass and ferrous metals. In Basel Convention, the guideline of waste containing mercury was prepared to manage mercury wastes soundly.

In this study, spent fluorescent lamps(SFLs) for 3 different types and brands are collected from local residences to estimate the components of spent fluorescent lamps. Mercury concentration in each component of SFLs is measured by DMA-80 after separation process for major components. And the distribution of mercury of 3 types of SFL is estimated by mercury concentration and mass for components to verify the portion of mercury in components between the types of SFL.

2. Experimental apparatus and methods

SFLs from 3 lamp companies are used in the crushing and the sieving system to separate the components of lamps. The

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specifications of selected linear fluorescent lamp(LFL), compact fluorescent lamp(CFL) and U type fluorescent lamp(UFL) from 3 lamp companies (A, B, C) are shown in Table 1. The specification of SFLs including mass of lamp can be varied with lamp company[6]. From the Table 1, it can be found that lamp manufactures may use different materials for either glass or phosphor powder.

An experimental apparatus of the crushing and separation used for SFLs in this study is as shown in Fig. 1. The experimental apparatus is composed of input guide assembly for inserting lamp, cam assembly for crushing, and separation assembly for recovery of glass, phosphor powder, plastics and others. In the experiment, a set of 10 SFLs is put into the experimental apparatus and then experimental apparatus is closed to prevent mercury vapor leaking from the apparatus. All mercury analyses for the parts of SFL are carried out by using Method 7473 (Mercury in Solid or Semisolid Waste-Manual Gold Amalgam Technique with atomic absorption spectrophotometer) using DMA 80. Three times of crushing tests for SFLs are conducted to obtain the average concentration of mercury for the same SFLs from 3 companies.

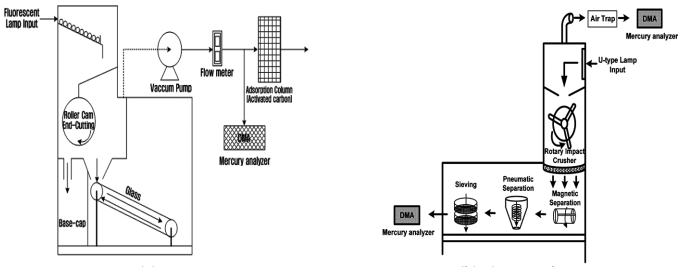
TABLE 1

Specification of SFLs from 3 lamp manufactures

Type	Company	Wattage (W)	Diameter (mm)	Length (mm)	Mass (g)
LFL	A	15	28	580	117.9
	B	15	28	580	94.5
	C	15	28	580	110.8
CFL	A	20	60	158	102.2
	B	20	60	158	102.7
	C	20	60	158	103.1
UFL	A	36	17.5	407	119.7
	B	36	17.5	407	118.2
	C	36	17.5	407	118.4

3. Results and discussion

The specification of major components from SFLs is shown in Table 2. The mass of glass among the major components such as glass, phosphor powder, plastics, and others in SFLs is much higher than that of other components. The average mercury concentration for major components of SFLs are shown in Table 3. The mercury concentration in phosphor powder is higher than 1,000 ppm for all cases, but the mass of phosphor powder is less than 2.0 g for 3 different types of lamps.



(a) LFL (b) CFL and UFL

Fig. 1. A schematic diagram of experimental apparatus for SFLs

Mercury concentration in the components of SFLs except phosphor powder can be less than 5ppm because phosphor powder can be completly separated with other components by using screen separations. If phosphor powder is not mixed with other components, in other words, the mercury concentration of other components is less than 5ppm which may be the regulatory level of mercury in EU [7].

For SFLs from 3 companies, the mercury concentration in the components of SFLs can be expressed in the order of A <C <B. Even though the characteristics of U-type lamp are almost the same in the lamp companies, it could be found that the amount of mercury used in the lamp greatly differs from manufactures. The mercury concentration in the components from B manufacture is higher than that of lamp from A manufacture. Since the amount of mercury used in the lamp is significantly different, the mercury concentration in the components may be found to be in the wide range.

TABLE 2

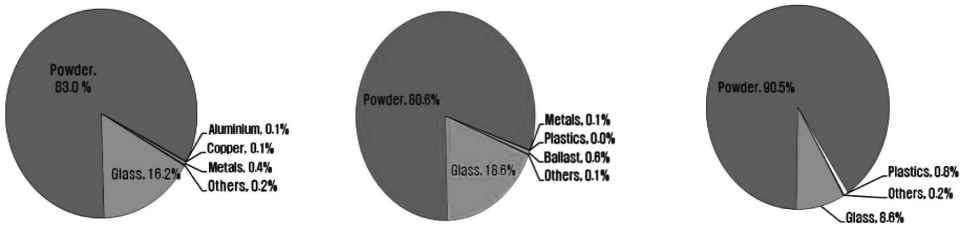
The major components of SFLs

Type	LFL(15W)			CFL(20W)			UFL(36W)		
	A	B	C	A	B	C	A	B	C
Glass	104.8	82.2	98.4	102.8	99.2	100.2	102.8	99.4	100.2
Powder	1.6	1.3	1.7	1.0	1.1	1.1	1.5	1.6	1.4
Aluminium	2.6	2.5	2.4	-	-	-	-	-	-
Copper	1.2	1.2	1.1	-	-	-	-	-	-
Plastics	-	-	-	11.3	13.0	12.5	11.4	13.0	12.5
Metals	2.9	2.9	2.8	1.3	1.4	1.8	-	-	-
Ballast	-	-	-	26.6	22.2	29.6	-	-	-
Others	4.8	4.5	4.4	3.4	3.7	2.6	4.0	4.4	4.1
Total	117.9	94.5	110.8	146.4	140.6	147.8	119.7	118.4	118.2

TABLE 3

Mercury concentration in the components from SFLs. [Unit : ppm]

Type	LFL(15W)			CFL(20W)			UFL(36W)		
	A	B	C	A	B	C	A	B	C
Glass	4.353	5.194	4.954	7.722	11.980	8.361	5.808	6.884	6.052
Powder	1,348.223	1,746.353	1,525.742	3,261.413	4,383.813	3,795.924	3,975.273	4,721.255	4,413.575
Aluminium	1.213	1.642	1.386	-	-	-	-	-	-
Copper	0.988	1.361	1.045	-	-	-	-	-	-
Plastics	-	-	-	0.134	0.211	0.159	4.335	4.975	4.553
Metals	4.285	4.293	4.332	1.288	2.840	2.483	-	-	-
Ballast	-	-	-	0.851	1.606	1.003	-	-	-
Others	0.865	1.425	1.111	1.896	2.420	2.283	2.303	2.906	2.773



(a) LFL (b) CFL (c) UFL

Fig. 2. Mercury distribution in the components of SFLs

The estimated mercury distribution in the components of SFLs is shown in Fig. 2. Regardless of lamp types and manufactures, the portion of mercury in phosphor powder and glass from SFLs is higher than 99% but the portion of mercury in other components was less than 1%. Lastly, the mercury amount in phosphor powder from SFLs company is estimated in the order of A <C <B.

4. Conclusions

By using separating techniques with crusher and sieving operator, SFLs from lamp manufactures (A, B, C) are separated into the major components such as glass, plastics, phosphor powder and others. The mercury concentration in the components from SFLs differs from lamp companies. The amount of mercury in components from SFLs is increased in the order of A <C <B and LFL(15W) <CFL(20W) <UFL(36W). From the results of mercury distribution, the portion of mercury amount in phosphor powder and glass tube is more than 99%. The mercury concentration in phosphor powder is extremely higher than that in other components, but the mass of phosphor powder is less than 2.0g for SFLs. Hence, it is desirable that phosphor powder of spent fluorescent lamps should be controlled separately and safely.

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